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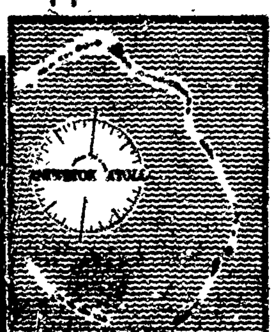
Operation IVY

PACIFIC PROVING GROUNDS

November 1952

Project 5.4b

FALL-OUT AND CLOUD-PARTICLE STUDIES



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FALL-OUT AND CLOUD-PARTICLE STUDIES

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Chemical and Radiological Laboratories
Army Chemical Center, Maryland
June 1953

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Part I

FALL-OUT STUDIES

By

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ABSTRACT

The major objectives of Project 5.4b, as set forth in Part I of this report, were to conduct the following studies in connection with the surface detonation of a thermonuclear device and an airdrop high-yield fission bomb:

1. To determine the fall-out pattern with its characteristics of activity, particle size, and radiochemical content on the land areas at Eniwetok Atoll.
2. To determine the rate of fall-out at various locations on Eniwetok Atoll during the first $6\frac{1}{4}$ hr after each shot.

The objectives were accomplished by (1) sampling the fall-out with intermittent-fall-out collectors, trays, wash tubs, and Tracerlab air monitors and by (2) analyzing the particulate matter for activity, decay, particle size, and radiochemical content.

Mike shot activities found from intermittent-fall-out collector samples 0.54 sq in. in area ranged from 10^{9} to 10^{13} dis/min. Upon conversion these activities ranged up to 2750 curies/sq ft. Mike shot radioactive fall-out was heaviest during the first 30 min after the detonation and continued for at least 6 hr after the detonation within 15 miles southeast from ground zero. The largest amounts of radioactive fall-out after Mike shot occurred at stations 6 to 10 miles southeast of ground zero up until $1\frac{3}{4}$ hr after shot time. From then on until about 5 hr after shot time, the heavier radioactive fall-out occurred at stations $3\frac{1}{4}$ to 6 miles from ground zero. The average Mike shot decay slope for all stations is -2.1 for the period of M + 190 to M + 500 hr.

In the region of Mike shot radioactive fall-out, over 90 per cent of the total particles analyzed were less than 1 μ in diameter. About 94 per cent of the radioactive particles which were found were larger than 10 μ. Less than 1 per cent of all the solid particles counted by light-microscope methods were radioactive, indicating that there is little internal radiological respiratory hazard.

Activities of King shot intermittent-fall-out collector samples were lower by a factor of 10^{3} to 10^{5}. These activities ranged up to 9.2×10^{-4} curies/sq ft. The average King shot decay slope for all stations for the period of K + 150 to K + 450 hr was -0.65.

PREFACE

This is the final report of Project 5.4b, Operation Ivy. It replaces the preliminary report of this project which was issued previously. This report was written as an aid to a more complete understanding of the nature of the cloud from a nuclear detonation, its time of arrival, and the radioactive-fall-out material from the cloud which was deposited on the surface of the ground.

The authors wish to express their appreciation to the personnel from the Chemical and Radiological Laboratories who contributed to the success of this project. A partial list of the personnel is included in Appendix A.

Particular appreciation is directed to James P. Mitchell, Chief, Radiological Division, and Elmer H. Engquist, Technical Assistant, who planned and directed the early phases of the project.

The authors also wish to acknowledge the assistance of Louis Totaro, Paul Schutt, and Pfc John Kemper for the design of the intermittent-fall-out collector equipment, and to Philip Krey, Sgt Richard Miller, Pfc Thomas Weldon, and Mrs. Barbara Ganser for their aid in preparing this report.

CHAPTER 1

OBJECTIVE

The objective of Project 5.4b was to conduct the following studies in connection with the surface detonation of a thermonuclear device and an airdrop high-yield fission bomb:

1. To determine the fall-out pattern with its characteristics of activity, particle size, and radiochemical content on the land areas at Eniwetok Atoll.
2. To determine the rate of fall-out at various locations on Eniwetok Atoll during the first $6\frac{1}{4}$ hr after each shot.
3. To determine the activity of the airborne particulate material near the surface of the ground on Parry Island, Eniwetok Atoll.
4. To obtain data on the activity, particle size, and radiochemical content of the particulate material comprising the cloud from a nuclear detonation by the use of snap samplers in F-84G jet aircraft.
5. To determine the residual gamma dose rate after each shot and the adequacy of aerial-survey systems in assessing the ground contamination (to be done in cooperation with the Radiological Safety organization).

Part I of this report will cover objectives 1 to 3; Parts II and III will cover objectives 4 and 5.

CHAPTER 2

BACKGROUND

2.1 INTRODUCTION

In past atomic detonations the results obtained from projects concerned with fall-out have not always been consistent. Fall-out results have been influenced by methods of collection and analysis, weather conditions, type and height of shot, and yields of the devices. However, results from past operations do show some trends which are of interest in this study.

2.2 SIGNIFICANCE OF RADIOACTIVITY AND PARTICLE SIZE

Radioactive fall-out can be both an external and an internal hazard to personnel.

External radiation can cause injury to body tissues of living organisms in the area of fall-out if the tissues are exposed to a large amount of radiation in a short time. One hundred roentgens (in a matter of minutes) has been suggested by the USAF Air Surgeon as a lifetime radiation dose which a soldier might be given in time of war.[1] This dose might produce some temporary blood-cell changes and a case of radiation sickness, but no permanent injury would be incurred by the soldier. No evacuation would be contemplated, and there should be no reduction in combat effectiveness.[2]

The internal hazard due to an aerosol depends, to a great extent, on the size of the radioactive particles inhaled. The nose will filter out almost all particles over 10 μ in diameter and about 95 per cent of all particles exceeding 5 μ. Particles of 0.5 to 5 μ are most likely to be retained in the lungs, or they may be transferred to the blood stream and the lymphatic system.[3,4] Internal contamination will also depend on the length of exposure to radioactive particles and the respirator rate. Particles of any size may be taken into the mouth, thus constituting an internal hazard.

In Operation Jangle Project 2.7, lung sections of dogs and sheep were examined.[4] Many crystalline particles 2 μ and under were found. The few radioactive particles found were in clusters and were alpha, alpha and beta, or beta emitters. Most particles either were never radioactive or had decayed to the point where no radioactivity could be detected at the time of examination. It is possible that the radioactive material had dissolved off the inert particles and had been redistributed. Lung tissues contained significant amounts of radioactivity as determined by counting techniques. The total internal dose was less than 1 per cent of the external dose from both shots, and the animals did not acquire significant amounts of radioactivity by inhalation or ingestion.

Radioactive fall-out may contaminate equipment to the point where it cannot be used safely for a period of time. Particles in the micron and submicron ranges are more difficult to remove mechanically than are larger particles. If these particles are radioactive, they can

present a serious contamination problem. Very large particles are more easily detected, measured, and removed by brushing and hosing.

2.3 PARTICLE SIZE, ACTIVITY, AND DISTANCE

Fall-out dust picked up on the USS Independence after Operation Crossroads Able shot indicated that the specific activity became larger as the particle radius decreased from 550 to 10 μ.[5] About 20 per cent of the total activity in the dust of the ventilation system of the USS Crittenden after Baker shot was in the 44- to 210-μ range; 51 per cent of the total activity in the same dust sample was 10 μ or less.[6] Both ships were approximately 600 yards from their respective ground zeros.

A moderate amount of activity[7] (up to 24 per cent) was found in particles 20 μ or smaller from Greenhouse Dog shot fall-out by Project 6.4. Greenhouse Easy shot samples indicated that greater than 92 per cent of the activity in the samples was associated with particles 20 μ or larger.

Estimates by the Greenhouse Radiological Safety Unit (Rad-Safe)[8] of the size of Dog shot radioactive-fall-out particles were made by comparison with red blood cells 7 to 8 μ in size. Thus examined, particles appeared to be 50 to 150 μ in diameter. Studies of mechanically separated particles indicated that fall-out during the first 6 hr after Dog shot was no smaller than 20 to 25 μ.

On Operation Jangle, Project 2.5a-1 sampled gross aerosol 7 ft above the ground with cascade impactors.[9] In an examination of the slides for particle-size distribution, no particles were found to be larger than 40 μ; the impactors may have shattered the larger particles. The tendency to smaller particle sizes in the aerosol at increasing distances from ground zero was observed after both shots. The underground-shot gross aerosol initially possessed a distribution containing slightly larger particles [number median diameter (NMD) 1.5 μ] than the surface shot (NMD, 1 μ). The underground-shot particles fell out faster than the surface-shot particles, and 50,000 ft from ground zero gross aerosol from both shots had an NMD distribution of less than 0.1 μ. No over-all correlation of activity with particle size could be made with the cascade impactors or any other sampling instrument used on this project. However, correlations were made with the data from some individual stations, showing the percentage of active particles from the surface-shot fall-out to be 0.01 per cent for 1-μ particles, whereas the percentage of active particles for underground fall-out particles of 100 μ was found to be 20 per cent.

Some Jangle underground-shot gross-fall-out samples were radioautographed.[10] Seventeen to eighteen per cent of all counted particles above 149 μ were radioactive, whereas only 0.9 to 4.2 per cent of the smaller size fractions were radioactive. These particles were collected 2000 ft northeast of ground zero.

Project 2.5a-2 found the gross-particle NMD for the underground shot to be 0.2 μ by electron-microscope analysis.[11] The radioactive-particle NMD was 1.4 μ. However, more than 93 per cent of the activity from both shots was associated with particles 20 μ or larger. Over-all area relations of activity with distance were not pronounced on the surface-shot fall-out. However, the underground-shot activity varied directly with distance from ground zero (within the limits of the experiment). For both shots the specific activity increased with distance.

The bulk of all radioactive dust collected at distances greater than 200 miles from ground zero was found to be less than 5 μ in diameter.[12]

2.4 RATE OF FALL-OUT

During the Sandstone tests[7] a secondary fall-out was reported from Kwajalein on Yoke + 1 day, 36 hr after the explosion and 400 miles southeast of Eniwetok. The fall-out occurred as radioactive rain that fell intermittently during a 10-hr period. The maximum activity was about 6 to 10 mr/hr.

On Operation Greenhouse[7] fall-out occurred over the southern half of the Atoll, starting about 3 hr after Dog shot and reaching a peak about 6 hr later. Activities ranged from 30 mr/hr at Eniwetok to 250 mr/hr at Rigili, from 1100 to 1700 hr on D-day. Fall-out from Easy shot was concentrated in the northern third of the Atoll. Activities ranged from 120 mr/hr at Piiraai to 3 r/hr at Bogallua on E-day, from 0700 to 1400 hr. A small secondary fall-out occurred on Parry and Eniwetok on E + 1.

Fall-out from the Jangle surface shot[11] was collected for 2 hr along a long narrow swath N10°E from ground zero. The first fall-out reached a station 14,000 ft from ground zero in 8 min. A second wave reached this section 60 to 100 min later. The first wave also reached a 20,000-ft station in 10 min; therefore the initial fall-out traveled approximately 20 to 23 mph to the two stations from ground zero. However, the surface wind actually traveled 2 mph; so the fall-out must have been carried by higher speed upper-altitude winds. Heavy fall-out from the Jangle underground shot covered a wider area, generally north-northeast from ground zero. There were three waves of fall-out recorded at stations 2000 and 3000 ft north of ground zero during the first 10 min after the detonation. At 14,000 and 20,000 ft north of ground zero, there was one pronounced wave during the first 15 min after shot time. Surface-wind velocity was only about 4.5 mph, whereas it was 21 mph at the top of the underground-shot cloud. There was a series of secondary fall-outs 30 to 100 min after the shot at the more distant stations. Individual sample activities from both shots were of the order of 10^8 counts/min during these peaks.

2.5 PHYSICAL CHARACTERISTICS OF RADIOACTIVE PARTICLES

Most of the Greenhouse radioactive particles were in the form of black spheres, which occurred as individual particles, particles adhering to coral grains, and clusters of spheres with transparent granules. The size of most of the particles ranged from 2 to 500 μ.

The Jangle radioactive particles were observed to be, generally, glassy spheres and grains.[11] Their elemental composition was the same as the inert soil, except that boron and carbon were missing. The Jangle fall-out was of a heterogeneous nature.

2.6 DECAY SLOPES

Decay slopes of a limited number of Operation Jangle underground-fall-out fractions, collected at distances from 2000 to 6000 ft northwest, north, or northeast from ground zero, varied from −0.45 to −1.44, with most of the slopes in the range of −1.1 to −1.3 between H + 1000 to H + 2000 hr.[8] It appears that the absolute values of the decay slopes increase as particle diameter decreases. Also, within the limitations of the data, the absolute value of the decay slopes appears to be relatively highest on the northeast leg from ground zero. The slopes decrease on the north leg and decrease further on the northwest leg. However, another investigator[13] found that decay slopes did not vary much for particles larger than about 300 μ. It is not known where these samples were collected in the test area.

2.7 RADIOCHEMISTRY

Previous radiochemical studies on samples collected from nuclear detonations have indicated a variation in fission-product activities with particle size.[7,8,14]

2.8 SUMMARY

An extensive review of the fall-out data given in the previous sections, including information on collecting apparatus, particle-size distribution of fall-out and aerosol near the surface,

decay, radiochemical results, fractionation, physical and chemical particle characteristics, activities, and energies may be found in reference 15.

Operation Ivy provided an opportunity to determine fall-out characteristics from a thermonuclear device and an airdrop high-yield fission bomb. These data will supplement previous atomic bomb phenomena observations in the determination of the hazards to personnel resulting from residual fall-out and airborne activity, the contamination of areas and structures, and in the development of decontamination measures.

CHAPTER 3

FIELD INSTRUMENTATION

Intermittent-fall-out collectors, flat trays, and wash tubs were used to sample fall-out on land areas at Eniwetok Atoll. Airborne activity in the cloud near the surface of the ground was measured on Parry Island with a Tracerlab air monitor.[16]

The intermittent-fall-out collector consists of a circular anodized aluminum disk, or "spider," divided into 24 sectors, a driving and timing mechanism, and a housing. The entire apparatus rests flush with the top of its concrete foundation (Figs. 3.1 and 3.2). A Blue Box* actuates the timing mechanism of the fall-out collector. In each sector is a triangular $3\frac{3}{8}$- by 10-in. tray (Fig. 3.3). One tray at a time is exposed to fall-out for 15 min through an opening of similar dimensions in the housing cover. Each tray holds four glass counting cups, 1 in. in diameter and $\frac{5}{16}$ in. high, coated with silicone; one glass slide with a silicone-coated collecting surface; one plastic slide on which four electron-microscope screens with films are mounted; and an 8-oz jar which is screwed onto the underside of the tray to collect liquid fall-out (Fig. 3.4). In addition, any solid fall-out in the tray may be brushed into the glass jar. On the underside of the spider are 24 cams, one for each sector, which operate a sector-selector positioning microswitch, and a spring cam which shuts off the timing mechanism at the end of sampling. Contamination of adjacent trays is minimized by a rubber gasket between the opening in the cover and the tray edges. The sampling opening on the cover is fitted with a spring-loaded sliding door (Fig. 3.5) to keep out rain and dust when the collector is not operating. The fall-out collector is set initially with the door closed and with tray 24 in the sampling position. When the fall-out collector begins operation, a cam on the top rim of the moving spider turns a lever which allows the door to spring open. At the same time tray 1 moves into sampling position. (Tray 1 is in sampling position during the period from 15 to 30 min after shot time, tray 2 is in sampling position from 30 to 45 min after shot time, and tray 3 is in sampling position from 45 min to 1 hr, etc.) The door remains open until all 24 trays have rotated through the sampling position, after which a cam near the center of the spider operates a lever to slide the door shut; the machine then shuts itself off.

The spider is driven by a 24-volt B-17 landing-gear motor, with magnetic clutch, through a 200 to 1 gear reducer and turntable (Fig. 3.6).

At the time of detonation the signal from a battery-operated Blue Box actuates a self-latching signal relay R_1 in the collector timing mechanism (Fig. 3.7). The current then flows from battery lead A through the sector-selector microswitch S_2, which is operated by the cam on the underside of the spider rim, thereby activating the interval timer S_1. The circuit is designed to open the door 15 min after the detonation to keep the inside of the intermittent-fall-out collector dry if a water wave passes over the station during the first 15 min. After the 15 min have elapsed, the switch in S_1 closes; then the positioning motor relay R_2 also closes,

*A photoelectric tube and its associated circuit which actuates a relay.

13

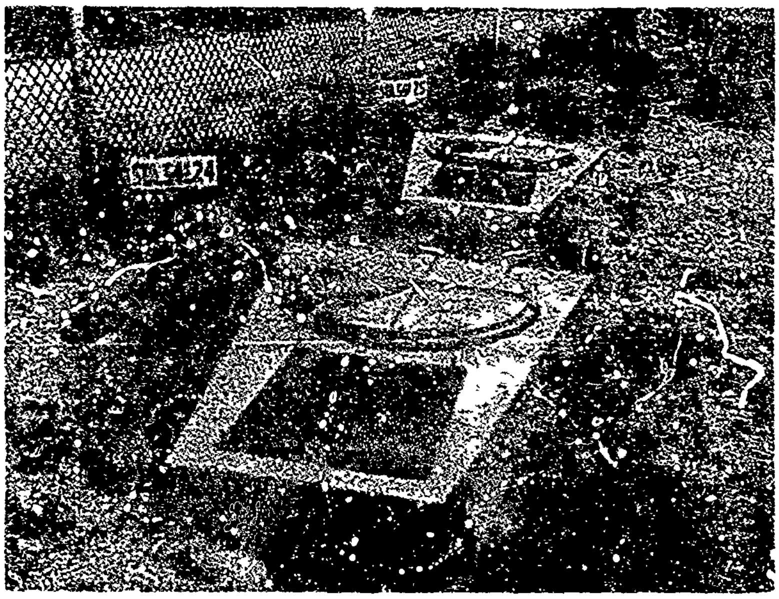


Fig. 3.1—General view of Station EE.

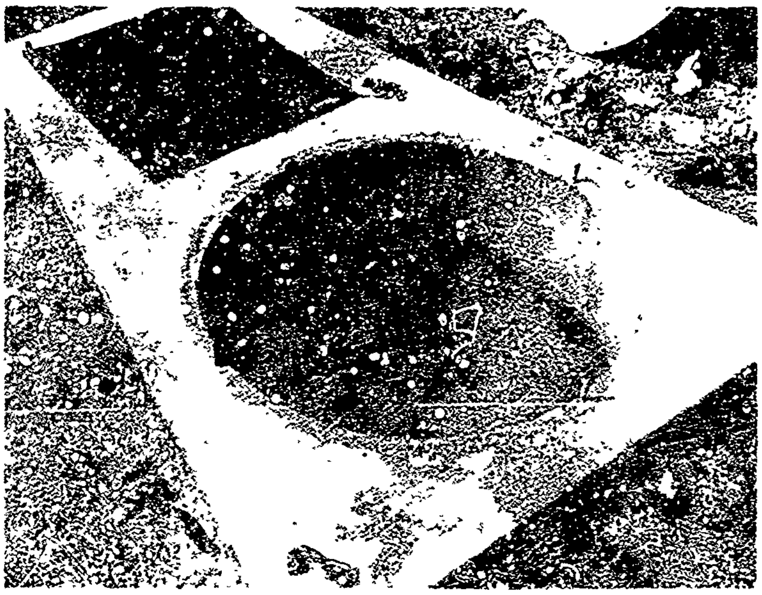


Fig. 3.2—Concrete foundation without sampling equipment.

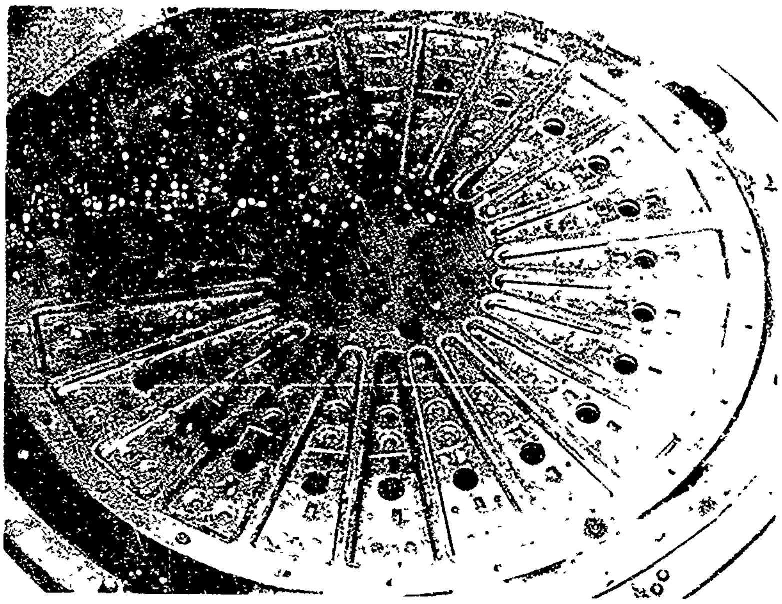


Fig. 3.3—Top view of spider and trays with total-fall-out slides and glass counting cups.

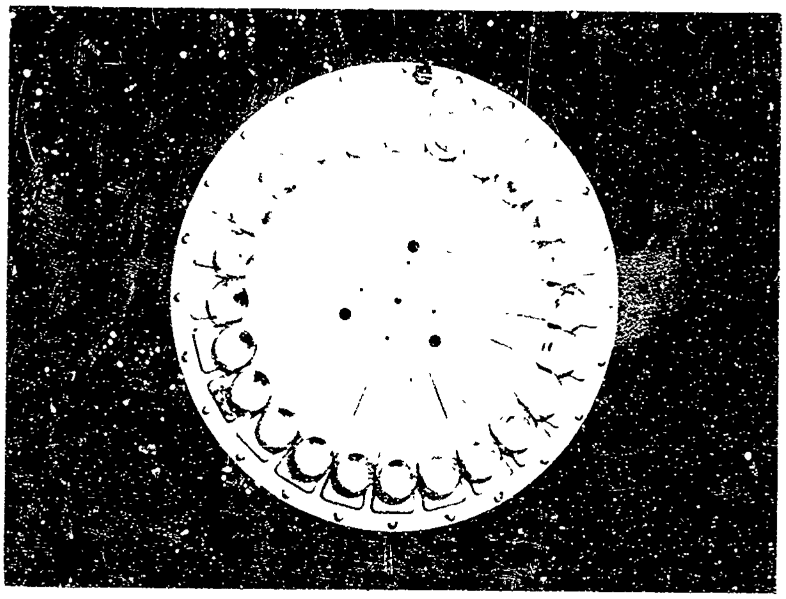


Fig. 3.4—Bottom view of spider, trays, and liquid-fall-out jars.

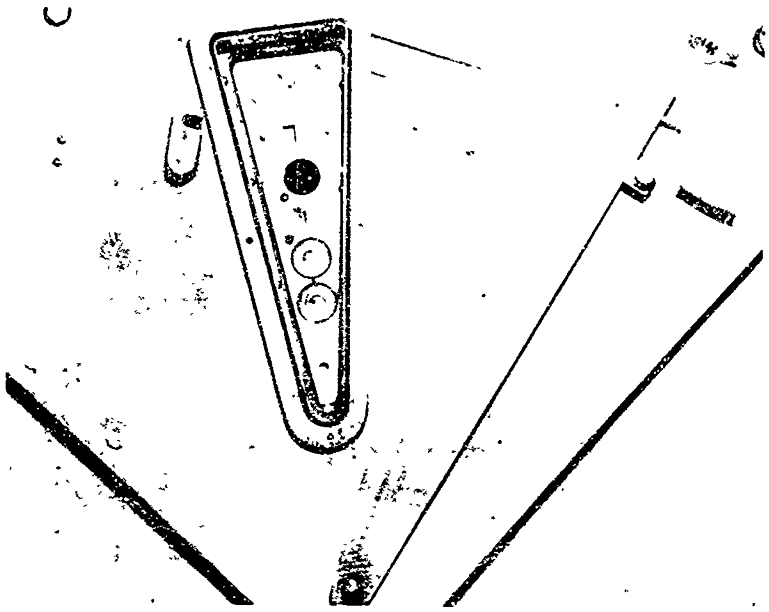


Fig. 3.5—Sliding door in open position. Tray underneath in sampling position.

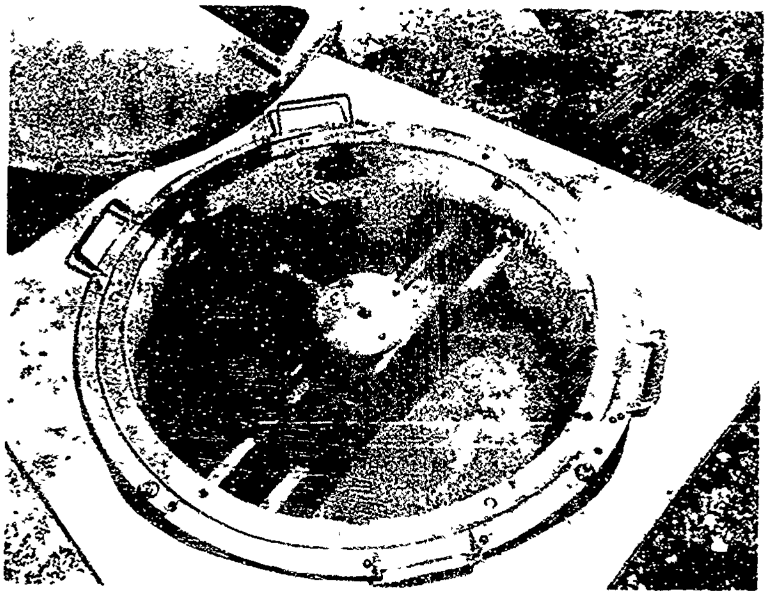


Fig. 3.6—Intermittent-fall-out collector interior, showing driving and timing mechanism.

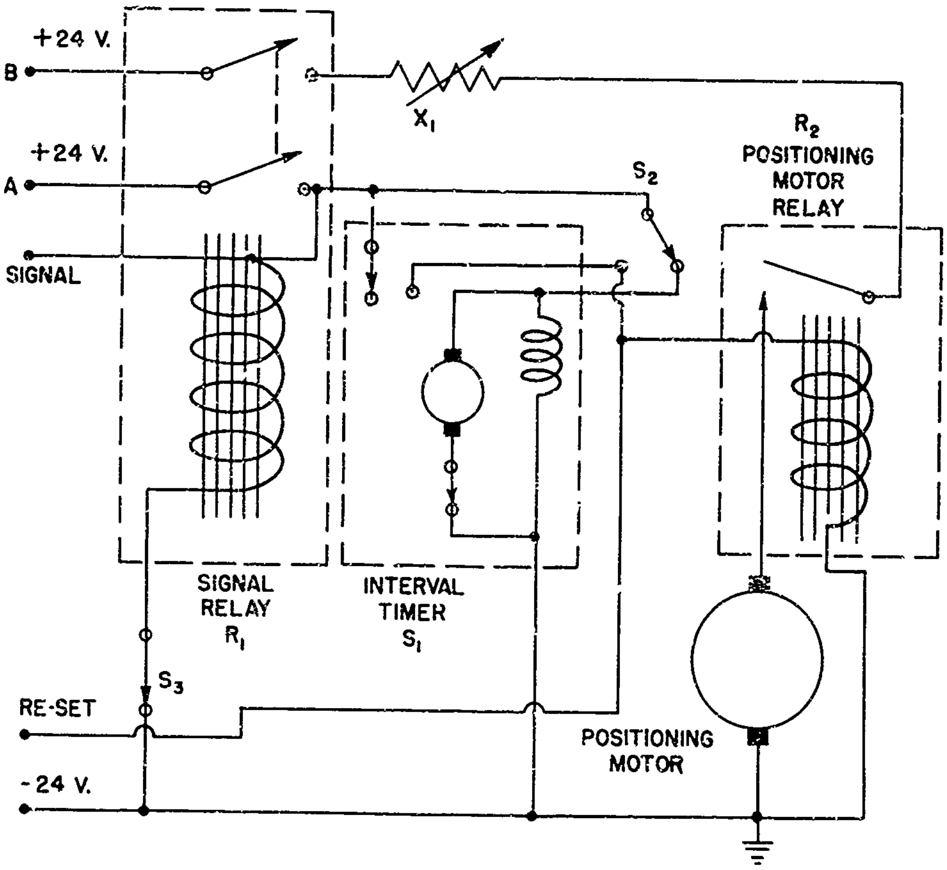


Fig. 3.7—Schematic diagram of intermittent-fall-out collector electrical circuit.

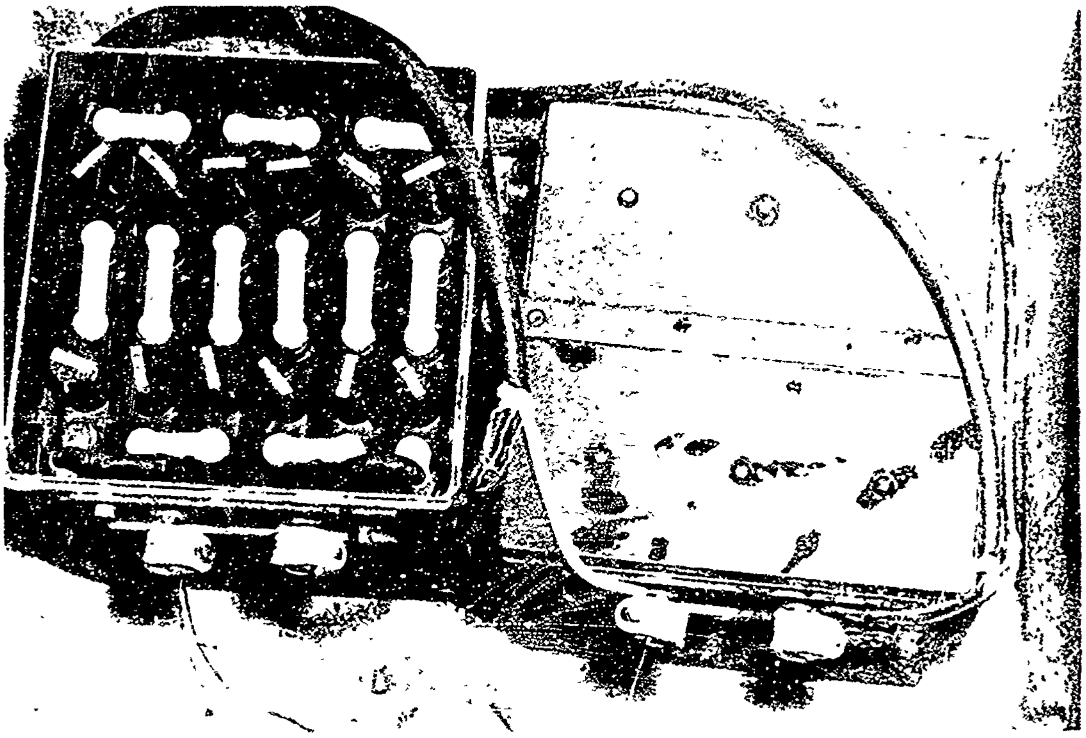


Fig. 3.8—Battery compartment.

and the positioning motor moves tray 1 into sampling position at the same time that the sliding door opens. Movement of the spider causes the cam of sector 24 to move off switch S_2, thereby disconnecting and resetting the timer S_1. When the cam on sector 1 presses and opens S_2, R_2 also opens and the positioning motor shuts off. At the same time S_2 completes the circuit for the timer S_1 and starts another cycle. Each sector is in the sampling position for 15 min. The electrical operation repeats itself until tray 24 is reached and has finished sampling. As tray 1 again moves into position, a cam near the center of the spider operates a door lever, thereby sliding the door shut. A spring cam opens switch S_3, shutting the machine off $6\frac{1}{4}$ hr after the detonation. The spring cam is so arranged that it passes over and does not contact S_3 when the machine is just starting to sample. The timing interval can be adjusted from 1 to 30 min. Resistance X_1 controls the positioning motor to reduce overshooting which is caused by faulty magnetic clutches and momentum. X_1 is simply a length of nichrome wire; the length of wire varies with the motor.

The body and cover of the collectors are made of 10-gauge steel and are rustproofed by a sprayed zinc coating. All the other parts are rustproofed where practicable. Power is supplied by two 24-volt 35-amp-hr batteries which are housed in a separate compartment of the foundation (Fig. 3.8).

Gross fall-out was collected in 33- by 36-in. trays with walls 1 in. high and/or 18-gal wash tubs. Airborne concentration of particulate matter at 4 ft above the ground was to have been measured by the Tracerlab air monitor.

CHAPTER 4

OPERATIONS

The Mike shot device was detonated on the ground surface at 0715 hr, 1 November 1952, Marshall Islands time. The King shot bomb was exploded at a height of 1500 ft at 1130 hr, 16 November 1952, Marshall Islands time.

Table 4.1 lists the code letters, code names, and the Micronesian names of the Eniwetok Atoll Islands. The distances from each station to Mike shot and King shot ground zeros are shown in Table 4.2. Figure 4.1 shows the position of each fall-out station in relation to Mike and King ground zeros.

During the three weeks prior to Mike shot, the intermittent-fall-out collectors were cleaned, installed in the concrete foundations, and wired to the Blue Boxes and batteries. Counting cups and slides were mounted in the spider trays in the Parry Island laboratory area. The complete spiders with trays, jars, cups, and slides were transported to the stations by LCM boats or helicopters in dust-tight boxes and then installed in the fall-out collectors. All equipment was set up for operation by M – 1 day.

Mike shot liquid and solid fall-out was to be sampled by 32 intermittent-fall-out collectors placed on islands A, B, C, I, J to P, R, S, U, V, W, Y, BB, DD, EE, FF, GG, KK, and LL. Duplicate stations were installed on islands J, R, Y, DD, EE, FF, KK, and LL. These duplicate stations are represented by the subscripts "n" or "s" in this report, e.g., R_n and R_s. When data from two stations have been averaged together, the average is represented by the subscript "ns" as LL_{ns}.

After Mike shot, a two-man recovery team visited each station by helicopter, removed the spiders with samples, placed them in the dust-tight boxes, and transported the boxes back to the laboratory area. The slides, cups, and jars were packaged for shipment, and the samples left Eniwetok for the Army Chemical Center by M + 5 days.

Because of the high residual activity at A, B, C, and I, these stations were not put in operation for King shot. However, an additional fall-out collector was installed at Coral Head, MM, making a total of 29 fall-out collectors ready for King shot. King shot station installation was completed by K – 1 day. Samples were shipped to the Army Chemical Center by K + 3 days.

Surface winds at a speed of 12 knots were generally from the east-southeast during and after Mike shot. King shot surface winds were from the east at a speed of 16 to 19 knots.

Gross liquid and solid fall-out was collected from islands O, P, R, S, U, V, W, Y, BB, DD, FF, GG, KK, LL, and MM after Mike shot and from islands P, R, S, U, BB, DD, GG, KK, and LL after King shot. Trays and tubes at stations J to N were blown away by Mike shot; the tray at Y was blown away by King shot. No gross fall-out was found at J to O, EE, FF, and MM after King shot.

One Tracerlab air monitor sampled on EE during and after both shots.

All field and laboratory equipment was packed and readied for shipment to the Army Chemical Center by K + 5 days.

Table 4.1 — SITE CODES FOR ENIWETOK ATOLL

Code letter	Code name	Island
A	Alice	Bogallua
B	Belle	Bogombogo
C	Clara	Ruchi
D	Daisy	Cochiti
E	Edna	San Ildefonso
F	Flora	Elugelab
G	Gene	Teiteiripucchi
H	Helen	Bogairikk
I	Irene	Bogon
J	Janet	Engebi
K	Kate	Muzin
L	Lucy	Kirinian
M	Mary	Bokonaarappu
N	Nancy	Yeiri
O	Olive	Aitsu
P	Pearl	Rujoru
R	Ruby	Eberiru
S	Sally	Aomon
T	Tilda	Biijiri
U	Ursula	Rojoa
V	Vera	Aaraanbiru
W	Wilma	Piiraai
Y	Yvonne	Runit
Z	Zona	"M" Site
AA	Alvin	Chinieero
BB	Bruce	Aniyaanii
CC	Clyde	Chinimi
DD	David	Japtan
EE	Elmer	Parry
FF	Fred	Eniwetok
GG	Glenn	Igurin
HH	Henry	Mui
II	Irwin	Pokon
JJ	James	Ribaion
KK	Keith	Giriinien
LL	Leroy	Rigili
MM	Mack	Lagoon photo tower (formerly called "Coral Head")

Table 4.2—DISTANCES FROM STATIONS TO MIKE AND KING SHOT GROUND ZEROS

	Distance to ground zero,* ft	
Station	Mike shot	King shot
A	17,423	78,100
B	13,462	76,500
C	7,799	73,500
I	9,270	64,600
J_n	18,895	53,800
J_s	18,905	53,800
K	21,521	49,800
L	23,756	47,300
M	31,053	40,700
N	34,852	37,800
O	36,943	35,100
P	40,274	32,500
R_n	44,532	29,800
R_s	44,587	29,800
S	47,899	26,600
U	53,300	22,300
V	54,820	19,700
W	57,211	15,100
Y_n	75,489	4,270
Y_s	75,495	4,270
BB	102,687	35,100
DD_n	110,949	47,600
DD_s	110,957	47,600
EE_n	115,565	55,800
EE_s	115,573	55,800
FF_n	124,609	70,000
FF_s	124,618	70,000
GG	117,510	87,600
KK_n	107,340	93,500
KK_s	107,350	93,500
LL_n	83,815	98,100
LL_s	83,817	98,100
MM	47,712	37,400

*King shot distances were estimated from Navy Hydrographic Office map 6033; Mike shot distances were determined by survey.

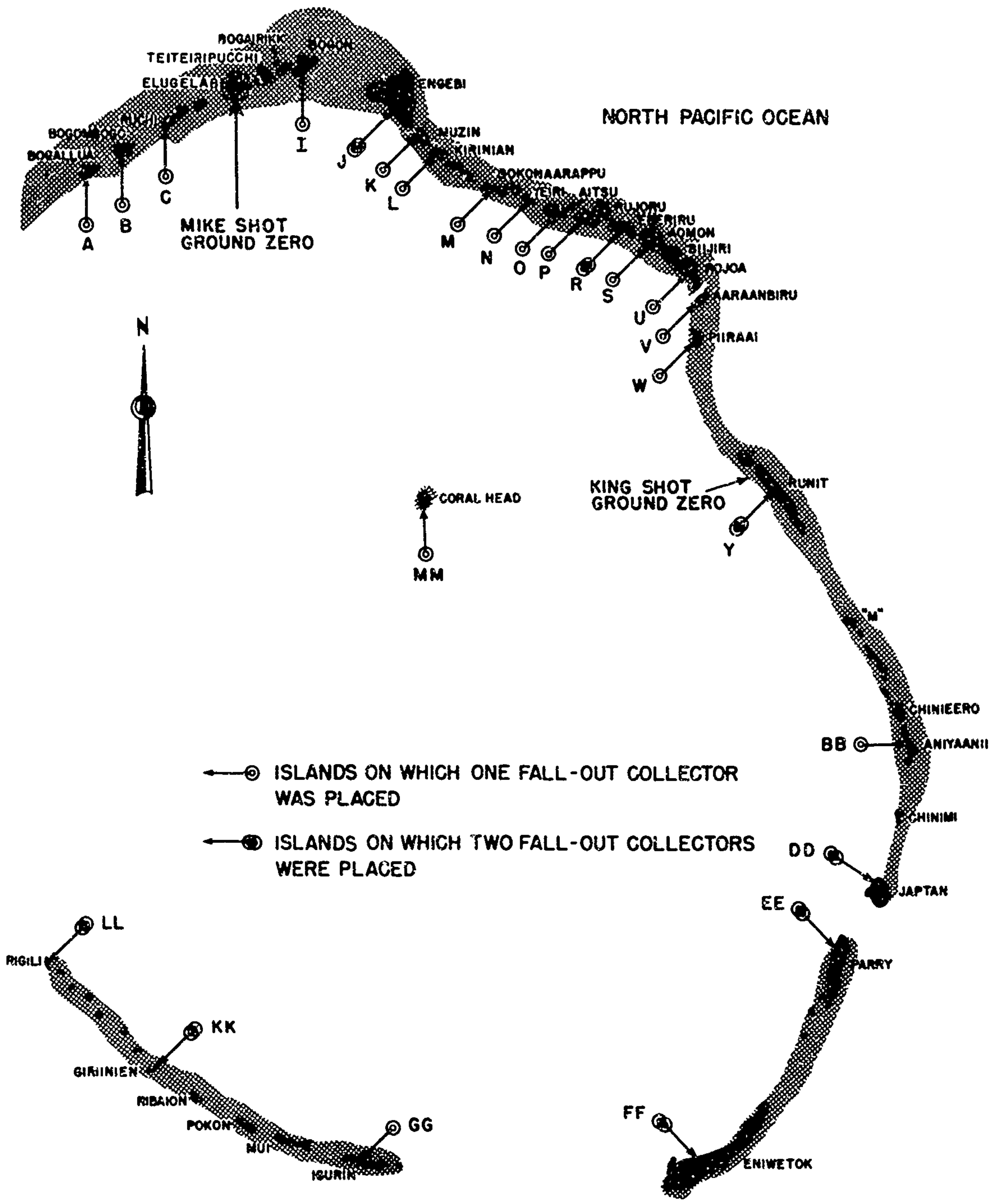


Fig. 4.1—Fall-out station locations at Eniwetok Atoll.

CHAPTER 5

ANALYTICAL METHODS

5.1 INTERMITTENT-FALL-OUT ACTIVITY AND DECAY MEASUREMENTS

The silicone-retained particles in the glass cups were monitored for relative activity. One cup from each tray was used for decay measurements; this cup was usually the most radioactive unless the activity was higher than that which the G-M tube could count without going into a continuous discharge. All cup samples which counted more than twice background were recounted in a Technical Associates model AL14A lead shield by vertically mounted Tracerlab 1AW53 G-M tubes with window thicknesses averaging 2.5 mg/cm^2. The G-M tubes were connected to model 1060 Atomic Multiscaler units. It was necessary to wipe the outside of the cups to prevent contamination of the counting apparatus.

For statistical validity all sample counts were normally duplicated, a total of 10,000 counts was obtained, and backgrounds were taken with each count for the same time interval. Because of the vast number of glass-counting-cup samples, these ideals were modified to fit the available time and facilities. All Mike samples were counted twice. If the activity was more than 2000 counts/min, the sample was counted to total at least 10,000 counts. Between a 1000 to 2000 counts/min rate, at least 5000 total counts were recorded. If the rate was less than 1000 counts/min, one 3-min count was taken. Initially it had not been planned to count those samples with activities lower than 500 counts/min because of time limitations. Fewer samples were radioactive than had been expected; hence, it was possible to count those samples less than 500 counts/min for 2 min. If the sample counted for less than 3 min, background was taken for the same period. A 3-min background was recorded for samples counted longer than 3 min, and a 2-min background was made for samples counting less than 1000 counts/min.

All King shot samples with a counting rate of over 2000 counts/min were counted to total 10,000 counts; those less than 2000 counts/min were counted for 5 min. Background was taken for 2 min each hour.

Actual counts per minute were corrected to disintegrations per minute by the use of a radium D source.

Decay analysis was done with the same counting equipment. Decay samples from each shot were counted over a period of 10 days.

5.2 PERCENTAGE OF TOTAL FALL-OUT WHICH WAS RADIOACTIVE FROM THE INTERMITTENT-FALL-OUT COLLECTOR SAMPLES

Two separate particle analyses were made: one was primarily concerned with the determination of the percentage of particles counted which were radioactive, using the light microscope, whereas the other (Sec. 5.4) was a complete (nonradioactive) analysis using a viewer, a light microscope, and an electron microscope.

After the activity and decay measurements were completed, the particles on the silicone-coated surface in the glass cups were transferred to the backing side of Eastman NTB stripping film, held taut by Duco cement on a plastic ring, with the emulsion side down. The particle transfer was made by washing the silicone and the particles with toluene under subdued light. Canada balsam, added before the toluene evaporated, formed a uniform medium for the particles which did not interfere with microscopic observation. The celluloid backing separated the emulsion from the silicone, toluene, and balsam; hence, during processing the particle medium was not disturbed (Fig. 5.1).

The Eastman NTB emulsion is considered best for detecting weakly ionizing particles, such as protons, mesons, and electrons, and is the emulsion most sensitive to beta particles. The film is insensitive to red light and cosmic background and has a 10-μ-thick emulsion and a 7-μ-thick backing.

After an empirically determined exposure time (approximately ~~as~~ follows: for a rate of 150,000 counts/min, one day; 20,000 counts/min, one week; 4000 counts/min, one month), the slides were developed using Du Pont x-ray developer poured onto the emulsion and retained by the plastic ring for 5 min at 20°C. Fixing and washing (for 10 min) were done similarly, without contacting the particle medium.

Particles were counted with a Bausch & Lomb Optical Co. research microscope, mounted on a microprojector base with carbon-arc illumination and used with a 20-power objective lens, 10-power ocular lens, and 5-power projection magnification, making a total enlargement of 1000×.

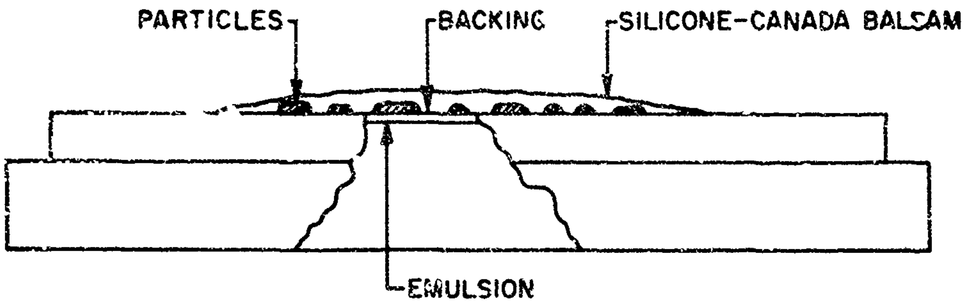
The particles were classified in 11 groups from under 2 μ to over 200 μ and also as to radioactivity or inertness. Statistical representation was sought for the ranges under 20 μ for each collection cup; so a total of at least 500 particles was counted in an arbitrarily chosen "average" diametrical strip. The ratio of radioactive to inert particles is considered statistically representative from 20 μ down for each cup; above 20 μ the total number counted was only enough to contribute to a ratio for the whole intermittent-fall-out collector.

5.3 PERCENTAGE OF TOTAL FALL-OUT WHICH WAS RADIOACTIVE FROM THE GROSS-FALL-OUT COLLECTOR SAMPLES

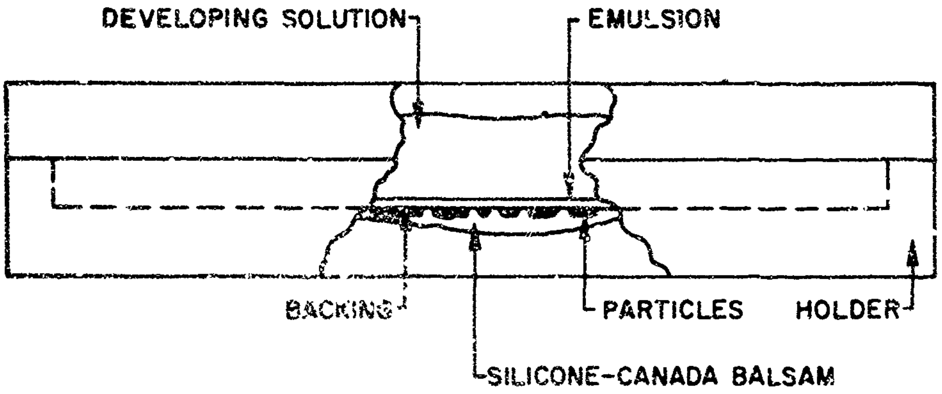
Water was decanted from the gross samples which were dried at 100°C and sieved through a nest of sieves mechanically shaken for 5 min. Calibration of this system, of which the smallest sieve had a 44-μ opening, indicated that most of the particles below 50 μ went through. The particle fractions retained by the sieves were used for radiochemical analysis and studies of decay rate vs size range (Sec. 6.3).

The small particle fraction which passed through the set of sieves was weighed and then processed by the standard method of soil analysis used by the U. S. Department of Agriculture.[17] Briefly it entailed treating with hydrogen peroxide to remove organic material, mixing with water plus a dispersing agent (Calgon), and overnight mechanical stirring of the suspension. A $^1/_{10}$-ml micropipetted fraction and a 25-ml pipetted fraction were removed at the times and depths calculated by Stokes' law to contain no particles larger than 20 μ, then none above 15, none above 10, none above 6, none above 4, none above 2, and none above 1 μ. The micropipetted fractions were deposited on grid-etched glass microscope slides, and the pipetted fractions were deposited on preweighed beakers and dried. The pipetted fractions were weighed to give the percentage of the total weight of each size range.

The micropipetted fractions were counted in the G-M setup described above, photomicrographed with 35-mm film, and radioautographed with NTB stripping film, emulsion side up. It was necessary to secure the film edges under the glass slide because so many of the strips wrinkled or curled, exposing the particles to chemical action. The film was developed with Du Pont x-ray developer for 5 min. Since the entire slide was immersed in processing the emulsion, some of the photographic solution penetrated the slightly permeable celluloid



PREPARATION POSITION



DEVELOPING AND EXAMINATION POSITION

Fig. 6.1 — Preparation of particle medium and developing position of stripping film.

backing. The gelatin served to protect the particles from damage. This method was used before the plastic frame was perfected and is inferior to that method since close contact between particle and backing is less certain. Both these methods were improvisations developed to replace NTB-emulsion-coated glass slides, which failed under actual conditions despite extensive prior testing. The apparent causes for this failure were

1 Some unknown difference in the contents of the sample cup which caused an impermeable coating over the emulsion, preventing development.

2. The presence of particles which reacted with the photographic chemicals.

The size distribution of the gross-fall-out collector samples was obtained by measuring the particles on the projected photomicrograph of the micropipetted slide. For the several size fractions all particles, totaling several thousand, in the microphotographs were counted and grouped. For all slides a representative gross size distribution was found. The ratio of radioactive to inert particles was determined by projecting the photomicrograph of the gelatin slide for measurement of particle size and by simultaneously examining microscopically the radioautograph area near the particle for darkening caused by radioactivity.

5.4 INTERMITTENT-FALL-OUT COLLECTOR TOTAL-FALL-OUT PARTICLE ANALYSIS

Previous work[9,18,19] has indicated the desirability of size-graded samples for the analysis of particulate material which includes a wide range of sizes. Since the usual size-grading sampling equipment (e.g., the cascade impactor) could not be used to sample fall-out, only a token size-grading was possible. Electron-microscope specimen screens, covered with a Formvar substrate, were used to collect the small-size range. The larger particles, which were not retained on the electron-microscope substrate and thus did not impede analysis of the small-size fraction, were collected on glass slides coated with a thin tacky film of Dow Corning Corp. silicone DC-801. The exact size range to be covered on each type of slide was not determined until actual field samples were available for examination.

One set of 24 field samples was analyzed at magnifications of 10, 20, 500, 1000, 10,000, and 50,000×. The data obtained were compared with similar analyses of six laboratory blanks. The blanks gave average backgrounds of 0.88, 0.15, and 0.07 particles per 100 μ^2 for the size ranges less than 0.1, 0.1 to 0.2, and 0.2 to 0.3 μ, respectively. Individual background values from the six blanks varied from zero to twice the average values stated above, and the number of particles greater than $^3/_{10}$ μ was found to be insignificant. The field samples gave values of less than 3, 10 to 20, and 10 to 20 times the average backgrounds of the three size ranges involved, and, considering the variation in background mentioned above, it was not possible to determine correctly the number of particles less than 0.1 μ. Practical considerations limited the number of magnifications at which each sample could be studied. Eventually the electron-microscope screens were analyzed for the size range from 0.1 to 2.0 μ at a final magnification of 10,000×. The silicone-coated slides were first analyzed for the range from 2.0 to 50.0 μ at a magnification of 500× and then reexamined for the range from 50 μ to 1 cm at 20×. The three sets of data obtained were corrected to a common area (1 cm^2) and then combined to give the complete particle-size distribution and concentration. The methods of projection counting and subsize classification employed have been outlined in previous reports.[9,18,19]

5.5 RADIOCHEMISTRY

Gross-fall-out samples from O, S, U, W, and MM stations were selected for analysis. All these samples, except that from O, consisted of solid and liquid phases; the sample from O was dry solid.

The samples were decanted and centrifuged. Some finely divided solid remained in the U sample after centrifugation and was dissolved by the addition of a little nitric acid. The liquid samples were diluted to 1 liter.

The solid phases from S, U, and W were dried 48 hr at 80°C, and the particles below 50 μ were removed by the wet-sieve technique for particle-size studies. The larger fractions were again dried and were size-graded by the dry-sieve technique into the fractions given in Table 5.1.

Table 5.1—GROSS-FALL-OUT FRACTIONS OBTAINED BY DRY SIEVING

Range, μ	Arithmetic mean, μ
< 73	77
73-81	88
81-96	105
96-114	125
114-136	150
136-162	178
162-194	212
194-230	
> 230	

The solid phase from MM station was rinsed from the centrifuge tubes with methanol, dried 24 hr at 80°C, and size-graded into the fractions given in Table 5.1. The sample from O was prepared in like manner. The particle sizes were checked microscopically.

The size fractions of 77, 105, 125, 150, and 212 μ from O, S, U, and MM were weighed and dissolved as follows: The sample was suspended in about 5 ml of water, and concentrated nitric acid was added drop by drop until effervescence ceased. The solutions were diluted to known values. The remaining fractions under 73 μ were used for measurement of percentage of hot particles (Sec. 5.3).

Sr^{89}, Zr^{95}, Mo^{99}, Ru^{103}, Ru^{106}, Ag^{111}, Ba^{140}, and Ce^{144} were determined by methods described in a previous report.[14] Standard methods of qualitative analysis and pH measurement were also applied to the samples.

CHAPTER 6

ANALYTICAL RESULTS

6.1 MIKE SHOT INTERMITTENT-FALL-OUT COLLECTOR ACTIVITY MEASUREMENTS

Results of beta activities for various time intervals of Mike shot fall-out collectors are shown in Table 6.1. These activities, in disintegrations per minute, are averages of the individual counting cups in each tray which had enough activity to be counted. In the tables given in this chapter, tray 1 corresponds to the period from $\frac{1}{4}$ to $\frac{1}{2}$ hr after shot time, tray 2 corresponds to $\frac{1}{2}$ to $\frac{3}{4}$ hr after shot time, etc. In a given tray the activities of the individual cups sometimes varied widely from the average; as an example of this variation, the activities of the individual cups at Mike shot J_n and J_β stations are shown in Table B.1. These two stations were the closest operating intermittent-fall-out collectors to Mike shot ground zero and were in the region of heavy fall-out.

These activities may be approximately converted into curies per square foot by applying the conversion factor

$$\text{Activity (curies/sq ft)} = (\text{dis/min})/(3.7 \times 10^{10}\ \text{dis/sec/curie} \times 60\ \text{sec/min} \times 0.545\ \text{sq in.} \times 1\ \text{sq ft/144 sq in.}) \qquad (6.1)$$

where 0.545 sq in. is the average area of one glass counting cup. This equation simplifies to

$$\text{Activity (curies/sq ft)} = (\text{dis/min})(1.2 \times 10^{-10}\ \text{curie} \times \text{min/dis} \times \text{sq ft}) \qquad (6.2)$$

Table 6.2 shows the activities in curies per square foot for seven time intervals at 10 stations.

6.2 KING SHOT INTERMITTENT-FALL-OUT COLLECTOR ACTIVITY MEASUREMENTS

King shot beta activities are shown in Table 6.3. These activities are lower than the Mike shot sample activities by a factor of 10^3 to 10^5. Table 6.4 shows the activity in curies per square foot for seven time intervals at seven King shot stations.

6.3 LOW AIRBORNE ACTIVITY

After both shots no detectable radioactive airborne concentration of particulate matter was found near the surface of the ground on EE with the Tracerlab air monitor.

Table 6.1 — MIKE SHOT BETA ACTIVITY CORRECTED TO SAMPLING TIME*
(Units of 10^3 dis/min)

	Station												
Tray	J_{ns}	K	L	M	N	O	R_{ns}	S	U	W	Average J to W	GG	LL_{ns}
1	7,840	28,100		22,900	60,900	110,000[c]	26,200	17,500	18,400	13,600	33,900		106
2	3,510	3,400	770	2,500	16,300	3,360	10,600	21,500	7,329	9,620	7,890		40.7
3	739	735	71.1	401	10,000[c]	170	6,240	10,300	11,300	1,590	4,150		621[c]
4	308	3,320	13.6	485	4,080[c]	10.5	5,380	17,200	1,890[b]	1,660	3,430		237
5	307	1,030	63.7	398	4,640	8.12	4,420	4,720	6,820[c]	1,880[c]	2,430		19.4
6	257	383	98.8	116[c]	2,530	3,350	2,030	2,500	6,010	622	1,790		289
7	130	3,750	12.9	92.9	1,305	3,160[b]	727	899	838	42.1	1,100		47.6
8	125	6,700	4.52	65.8	933	2,830[c]	244	277	582	7.87[b]	1,180		23.2
9	55.3	984	5.04	31.9	483	1,120	47.3	30.3	42.5[c]	0.501[a]	280	0.291	20.9
10	61.3	4,650[c]	1.15	77.4	558[c]	276	63.0	24.4	0.401[b]	1.94[b]	571	0.163[c]	55.9
11	32.6	158	8.25	178	222	80.7	11.0	11.0	13.6	0.265[a]	71.5	0.332[c]	0.792
12	62.5	2,220	0.874	64.4	65.4	28.2	42.2	8.11	157	0.374	265	0.447[a]	3.81
13	45.2	106	17.6	32.5	43.6[c]	3.15	54.0	19.1	1.24[c]	39.0[a]	36.1		0.304
14	39.9	857	30.6	17.0	5.78[c]	6.12	12.6	3.77	18.9[c]	0.236[b]	99.2		2.70
15	37.2	12.2	38.4	12.6	9.18	36.0	3.23	12.4	0.789[a]	0.170[a]	16.2		0.102[a]
16	29.6	30.5	17.4	5.08	16.5	1.55	2.66	0.338[b]	0.286[b]	0.407[b]	10.4		0.446[b]
17	11.7	58.5	7.02	7.66	25.2	1.09	3.63	21.7[c]	1.85[a]		15.4		0.0622[a]
18	4.83	8.19	12.5	2.96	3.05	0.362	0.903	11.9[c]	2.01[b]		5.19		
19	8.39	40.5	8.38	1.05	12.9	7.74[c]	2.60	0.197[a]	0.542[b]	0.758[a]	8.10		0.0643[a]
20	11.3	10.0	8.39	2.16	1.98	5.35	4.27	5.25[c]	18.4[c]	0.119[a]	6.72		
21	8.32	8.40	3.04	3.25	5.72[b]	0.218	0.945	7.44	10.9[a]	1.39[a]	4.96		
22	11.1	22.8	1.92[c]	8.97[c]	3.25	3.88	1.47	0.296	0.270[c]	0.998[a]	5.50	0.292[a]	0.238[b]
23	12.5	15.4	2.71	9.14	1.33	12.0	3.58	0.469	18.3	0.247[b]	7.57	0.0267[a]	
24	7.63	71.7		31.6	17.6	92.2	7.62	31.8	50.5	168.0	53.2		

*In general, the activities throughout this table are averages of counting-cup data from four cups in each tray. In some trays not all cups had enough activity to be counted. Superscript "a" indicates one cup was counted, "b" indicates two cups were counted, and "c" indicates three cups were counted.

Table 6.2—MIKE SHOT INTERMITTENT-FALL-OUT COLLECTOR BETA ACTIVITY
(Units of 10^{-2} curies/sq ft)

	Time after detonation, hr						
Station	$\frac{1}{4}$ to $\frac{1}{2}$	$\frac{3}{4}$ to 1	$1\frac{3}{4}$ to 2	$2\frac{3}{4}$ to 3	$3\frac{3}{4}$ to 4	$4\frac{3}{4}$ to 5	$5\frac{3}{4}$ to 6
J	9,410	837	156	39.1	44.6	76.7	15.0
K	33,700	882	4,500	190	14.6	48.6	18.5
L		85.3	15.5	9.90	46.1	10.0	3.25
M	275,000	481	111	214	15.1	1.26	11.0
N	73,100	12,000	1,360	266	11.0	15.5	1.60
O	132,000	204	3,790	96.8	43.2	9.29	14.4
R	31,400	7,490	872	13.2	3.88	3.12	4.27
S	21,000	12,400	1,080	13.2	14.9	0.236	0.563
U	22,100	13,600	1,010	16.3	0.947	0.650	22.0
W	16,300	1,910	50.5	0.342	0.488	0.143	0.296

Table 6.3—KING SHOT BETA ACTIVITY CORRECTED TO SAMPLING TIME*
(Units of 10^5 dis/min)

Tray	Station													
	J_{ns}	K	L	M	N	O	P	R_{ns}	S	U	V	W	LL_n	LL_s
1	77.1	28.2	12.2	153	31.1[a]			49.1	12.9[b]	156[a]	11.7[a]			
2	23.6	11.1	23.4	9.29		22.2		23.0[b]	10.6[a]					
3	20.6	11.6	7.95	4.50	43.3[a]	4.95[b]		9.61	5.97[a]					
4	24.5	4.27	16.9	18.5		7.07[a]							16.7[a]	12.9[b]
5	12.9	1.44	7.92	8.01		3.37[a]		5.53[b]	45.2[b]					
6	14.3	0.733	8.51	1.25		7.11[a]		4.47[b]				10.1[a]		
7	9.83	1.06	8.92	1.35		1.96[a]		3.54[a]	4.98					
8	7.57	1.59	5.17	2.16		2.01[a]		4.26[b]	4.32[b]					
9	5.33	1.17	3.81	0.286[a]		27.3[a]		4.20[b]	4.45[a]					
10	13.3	0.694	2 62	0.191[a]				2.16[b]	3.19[a]	3.49[a]				
11	8.31	1.45	4 69	0.503		2.04[a]		14.9			14.3[a]			
12	21.4	1.73	4 83[b]	11.8		5.68[a]		1.70[b]		2.84[a]				
13	13.6	1.29	3.77	0.520		1.97		3.62[b]						
14	7.26	1 84	8.39	1.68		12.9[a]	5.45[a]	2.23[a]					2.14[a]	
15	7.08	0.919	6.21	1.63		3.38[a]		2.41[a]				7.30[a]		35.2[a]
16	3.61	1.96	3.83	0.810		0.878[a]	45.9	1.85[b]	15.4[a]					
17	3.59	2.30	8.75	1.16		1.18[a]	3.21[a]	1.49[a]	4.02[a]					
18	4.00	3.79	4.28	0.65		2.64[a]		4.34	5.38[a]					
19	5.44	5.23	8.06	1.30				1.69[b]						
20	2.85	2.90	4.00	2.00				3.82						1.54[a]
21	3.13	1.76	4.36	8.46				1.30	3.34[a]					
22	3.88	4.28	1.68	2.98			3.27[b]	4.63		3.08[a]				
23	2.67	5.47	6.15	9.06				2.57		2.86[b]				
24	2.56	4.23	4.75	1.67				4.65	30.9			1.15[b]		

*In general, the activities throughout this table are averages of counting data from three cups in each tray. In some trays not all cups had enough activity to be counted. Superscript "a" indicates one cup was counted, and "b" indicates two cups were counted.

Table 6.4—KING SHOT INTERMITTENT-FALL-OUT COLLECTOR BETA ACTIVITY
(Units of 10^{-5} curies/sq ft)

Station	Time after detonation, hr						
	¼ to ½	¾ to 1	1¾ to 2	2¾ to 3	3¾ to 4	4¾ to 5	5¾ to 6
J	92.5	24.7	11.8	9.97	8.50	6.53	3.20
K	33.8	13.9	1.27	1.74	1.10	6.28	6.56
L	14.6	9.54	10.7	5.63	7.45	9.67	7.38
M	184	5.40	1.62	0.604	1.96	1.56	10.9
O		5.94	2.35	2.45	4.06		
R	58.9	11.5	4.25	17.9	2.89	2.03	3.08
S	15.5	7.16	5.98				

6.4 SPECIFIC ACTIVITIES OF MIKE SHOT GROSS-FALL-OUT SIZE FRACTIONS

The pipetted size fractions from S, U, V, and W stations were deposited and dried on a slide, weighed, and counted as described in Sec. 5.3. The results, in counts per minute per milligram, and the corresponding weights of the fractions for four stations are shown in Table 6.5. Fall-out from Y, LL, and MM was so small in quantity that it was not fractionated and, hence, not counted.

6.5 DECAY MEASUREMENTS FROM INTERMITTENT-FALL-OUT COLLECTOR SAMPLES

Beta decay slopes are listed in Table 6.6 for Mike shot and in Table 6.7 for King shot. Representative slopes for Mike and King shots are shown in Fig. 6.1. The numerical average slope for all Mike shot stations is −2.1 for the period of M + 190 to M + 500 hr. The King shot numerical average slope from K + 150 to K + 450 hr is −0.65. It should be emphasized that the King shot decay slopes were based on a small quantity of fall-out.

6.6 DECAY SLOPES FROM FRACTIONATED GROSS FALL-OUT

Solid gross fall-out from Mike shot MM station was fractionated by sieving. The decay slopes (Table 6.8) were determined for the fraction retained by each sieve. Decay slopes were determined for Mike S and MM stations liquid fall-out. These slopes were −1.85 and −2.14, respectively, from M + 800 to M + 1100 hr.

6.7 MIKE SHOT CONTAMINATION OF KING SHOT SAMPLES

The question arose as to whether the activity picked up in the intermittent-fall-out collector during King shot was residual contamination remaining in the area from Mike shot. Four samples which had been used to determine Mike shot decays were counted until K + 20 days. Their slopes during this time ranged from −1.68 to −1.99.

King shot beta decay slopes, determined during this same period of time, ranged from −0.62 to −0.99, with an average of −0.65. It is therefore believed that the activity of the King shot samples is principally due to King shot fall-out.

6.8 ABSORPTION MEASUREMENTS

Several Mike shot samples were counted over a period from M + 19 to M + 45 days, using Tracerlab aluminum absorbers. The resulting decay slopes are listed in Table 6.9.

6.9 PERCENTAGE OF MIKE SHOT TOTAL FALL-OUT WHICH WAS RADIOACTIVE FROM THE INTERMITTENT-FALL-OUT COLLECTOR SAMPLES

The percentages of Mike shot total fall-out which were radioactive from the intermittent-fall-out collector samples are shown in Table 6.10. The average result is shown graphically in Fig. 6.2. Results are in three sections for each station and in each size range. Column a is the cumulative percentage less than and including the stated size range of the total number of particles counted. Column b is the percentage of the number of particles in each size range which are radioactive, and column c shows the cumulative percentage less than and including the stated size range of radioactive particles counted. The actual numbers of radioactive and total particles counted and the over-all percentage of the number of radioactive particles counted at each station are also listed.

Table 6.5 — SPECIFIC ACTIVITIES AND WEIGHTS OF PIPETTED FRACTIONS OF MIKE SHOT GROSS FALL-OUT

	Station							
	S		U		V		W	
Pipetted fraction, μ	Activity, counts/min/mg	Weight, mg	Activity, counts/min/mg	Weight, mg	Activity, counts/min/mg	Weight, mg	Activity, counts/min/mg	Weight, mg
0–20	20,150	2,640	12,720	1,340	9,890	880	1,440	840
0–15	13,350	2,450	7,140	1,250	13,250	620	9,870	760
0–10	23,150	2,130	7,090	1,050	5,140	710	13,800	630
0–6	22,900	1,960	6,380	870	14,550	530	29,600	540
0–4	12,090	1,810	5,480	700	5,180	480	5,890	500
0–2	9,680	1,370	3,570	530	3,300	320	3,410	320
0–1	149	1,020	1,755	310	158	120	15,250	050

Table 6.6 — MIKE SHOT BETA DECAY SLOPES FROM M + 190 TO M + 500 HR*

Tray	Station†														
	J_n	J_s	K	L	M	N	O	R_n	R_s	S	U	W	GG	LL_n	LL_s
1	−1.86	−1.94	−1.56				−1.49	−1.59	−3.11	−1.79	−2.04	−2.17		−2.23	−1.52
2	−2.32	−2.20	−1.48	−2.12	−2.19	−0.967	−2.67		−2.43		−2.08			−1.55	−1.86
3	−1.67	−1.70	−1.90	−2.27	−1.82	−1.27	−2.41		−2.56	−1.12		−1.98		−2.19	
4	−2.33	−2.55	−2.09	−1.71	−2.10	−1.04	−2.11	−1.05	−1.82			−2.16		−1.88	
5	−2.25	−2.36	−2.90	−2.55	−1.86			−2.15	−1.81	−1.26		−1.83		−1.22	−1.63
6	−1.77	−2.44	−1.53		−2.23	−1.50	−1.99	−1.73	−2.66	−1.40		−1.82		−2.23	−2.21
7	−1.83	−2.38	−2.34		−2.12	−1.50		−1.87	−2.24	−1.65	−2.18				−2.26
8	−1.77	−2.65	−3.03		−1.93	−1.68	−1.18	−1.61	−2.63	−1.79	−2.39			−2.20	−2.45
9	−1.52	−2.28	−1.90		−2.47	−2.14	−1.98	−2.30	−3.21	−2.30	−2.31			−1.38	
10	−1.85	−2.18	−1.88	−1.88	−2.52	−1.70	−2.24	−2.40	−3.17	−2.09				−2.25	−2.04
11	−2.17	−2.53	−1.56	−2.31	−2.09	−1.73	−2.55		−3.03	−2.87	−2.25		−1.86	−1.87	
12	−1.93	−2.58	−1.33	−1.63	−2.10	−1.70	−2.35		−2.90	−2.09	−2.48				−2.51
13	−1.74	−1.92	−1.77	−2.32	−1.94		−2.36	−0.863	−2.10	−2.07	−2.56	−2.16		−2.06	
14	−1.82	−2.11	−2.28	−2.15	−2.17		−2.54		−3.25	−1.98				−2.26	
15	−1.71	−2.36	−1.83	−1.42	−2.14	−1.86	−2.57	−1.60	−0.621	−1.46					
16	−1.62	−2.62	−1.91		−1.89	−1.86	−2.39		−2.87			−1.53			
17	−1.76	−2.24	−2.13	−1.59	−2.00	−2.02	−2.37		−1.77	−1.82	−2.46	−2.31			
18	−1.96	−1.75	−2.31	−2.12	−0.983	−2.50			−2.40	−1.79	−1.40				
19	−1.97	−2.23	−1.75	−2.30	−2.23	−2.92	−2.20		−2.68			−2.33			
20	−2.37	−2.32	−2.02	−2.55	−1.76	−2.00	−2.12		−2.80		−2.40				
21	−2.04	−2.22	−2.34	−3.33	−1.98	−2.42		−1.04	−2.30	−1.00	−1.85	−2.32			
22	−2.00	−2.36	−2.63		−2.37	−2.01	−2.22		−3.01	−3.56		−2.21		−2.34	
23	−2.78	−2.02	−2.32	−2.51	−2.21	−2.92	−2.06		−3.02	−1.41	−2.35				
24	−2.63	−2.24	−1.47		−2.35	−1.32	−2.06		−2.24	−2.97	−2.02	−2.23			
Average	−2.12‡		−2.01	−2.11	−2.07	−1.85	−2.19	−2.25§		−1.92	−2.20	−2.09	−1.86	−1.97	−2.06

* The decay slope is the exponent in the expression $A_t = A_1 t^{-n}$.
† Average slope of all stations, −2.1.
‡ Average of J_n and J_s.
§ Average of R_n and R_s.

Table 6.7—KING SHOT BETA DECAY SLOPES FROM K + 150 TO K + 450 HR*

	Station†						
Tray	J_8	M	N	O	P	R_8	S
1	−0.692	−0.560					
2	−0.601						
3			−0.659				
4		−0.721					
5							
6							
7							
8							
9				−0.634			−0.728
10	−0.677						
11							
12	−0.668	−0.548					
13	−0.400						
14	−0.647						
15	−0.623						
16					−0.670		−0.512
17							
18							
19							
20							
21		−0.727				−0.610	
22					−0.928		
23		−0.574					
24	−0.658		−0.644				−0.858
Average	−0.621	−0.626	−0.652	−0.634	−0.799	−0.610	−0.699

*The decay slope is the exponent in the expression $A_t = A_1 t^{-n}$.
†Average slope of all stations −0.65.

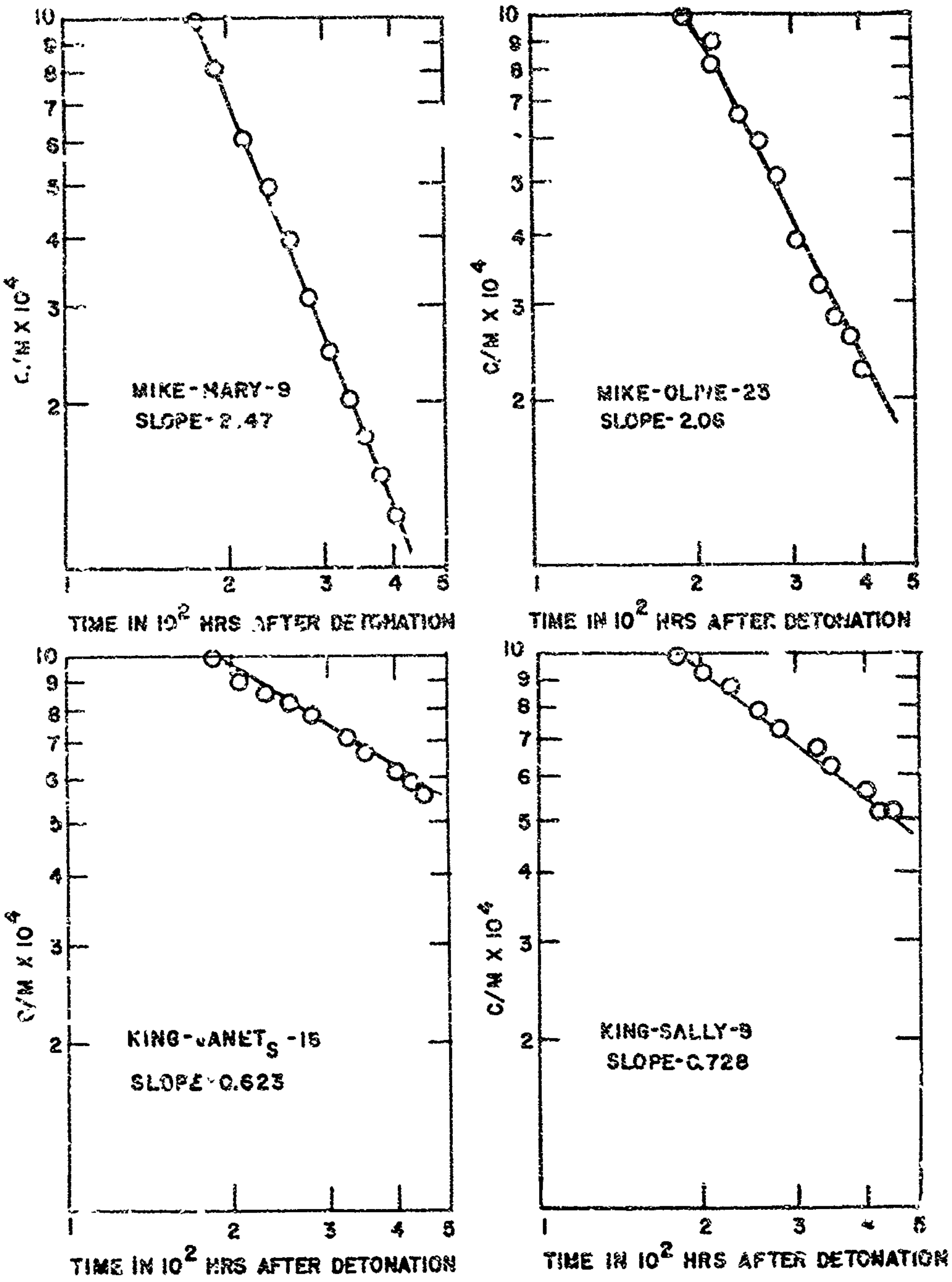


Fig. 6.1—Examples of Mike and King shot decay slopes.

Table 6.8 —MIKE SHOT DECAY SLOPES FROM FRACTIONATED GROSS FALL-OUT, STATION MM*

Average particle size, μ	Slope
77	−1.07
105	−1.23
125	−1.30
150	−1.66
212	−1.85

*From M + 600 to M + 1100 hr.

Table 6.9 —MIKE SHOT DECAY SLOPES FOUND WITH ALUMINUM ABSORBERS*

Station and tray	Aluminum absorber thickness, mg/cm²						
	1.79	7.03	22.0	106.0	268.0	327.0	1590.0
K11	−1.07	−2.01	−1.78	−1.09	−0.64	−0.61	−1.37
L1	−2.16	−2.02	−1.88	−1.25	−0.81	−0.83	−1.54
N4	−1.96	−1.88	−1.71	−1.19	−0.82	−0.87	−1.61
R_{us}	−2.00	−2.09	−1.87	−1.22	−0.75	−0.79	−1.53
S1	−1.81	−1.72	−1.57	−1.11	−0.82	−1.01	−1.83

*From M + 19 to M + 45 days.

Table 6.10 — SUMMARY OF INTERMITTENT-FALL-OUT COLLECTOR RADIOACTIVE- AND TOTAL-PARTICLE-SIZE DATA, MIKE SHOT*

Size range, μ	Station J_{ns} a	Station J_{ns} b	Station J_{ns} c	Station K a	Station K b	Station K c
1–2	68.62			53.20		
2–4	81.78	0.02	1.88	70.56		
4–6	88.17	0.05	3.77	81.94		
6–10	92.36	0.09	5.66	89.35	0.09	1.66
10–15	94.41	0.37	9.43	92.90	0.62	6.66
15–20	96.32	0.40	13.20	95.47	2.00	18.33
20–30	97.77	0.26	15.09	97.14	1.78	25.00
30–40	98.46	1.65	20.75	97.99	3.44	31.66
40–50	99.02	6.20	37.73	98.75	4.90	40.00
50–200	99.77	11.67	81.13	99.70	18.60	80.00
>200	100.00	16.94	100.00	100.00	30.00	100.00

Total number of particles counted: Station J_{ns}, 26,144; Station K, 13,538.

Number of radioactive particles counted: Station J_{ns}, 59; Station K, 60.

Percentage of radioactive particles: Station J_{ns}, 0.22; Station K, 0.44.

Size range, μ	Station L a	Station L b	Station L c	Station M a	Station M b	Station M c
1–2	62.43			63.45		
2–4	78.38			79.98		
4–6	87.37			87.91		
6–10	91.47	0.23	50.00	92.37		
10–15	93.98			94.53		
15–20	96.07			96.50	0.40	8.33
20–30	97.64			98.12	0.48	16.67
30–40	98.69			98.72		
40–50	99.35	1.47	100.00	99.32	3.95	41.67
50–200	99.92			99.89	6.76	83.33
>200	100.00			100.00	15.38	100.00

Total number of particles counted: Station L, 10,398; Station M, 12,805.

Number of radioactive particles counted: Station L, 2; Station M, 12.

Percentage of radioactive particles: Station L, 0.02; Station M, 0.09.

*For an explanation of columns a, b, and c, see Sec. 6.9.

Table 6.10 — (Continued)

Size range, μ	Station N a	Station N b	Station N c	Station O a	Station O b	Station O c
1-2	53.16			67.55		
2-4	73.43			80.07		
4-6	83.89	0.07	0.68	87.62	0.10	6.67
6-10	90.60	0.33	2.73	92.38		
10-15	93.99	0.88	5.47	94.98	0.29	13.33
15-20	96.32	1.93	9.58	96.73	0.86	26.67
20-30	97.81	6.56	18.49	98.19	0.52	33.33
30-40	98.43	16.87	28.08	98.87	1.12	40.00
40-50	98.92	31.82	42.46	99.18		
50-200	99.75	59.09	86.98	99.82	4.76	66.67
>200	100.00	57.58	100.00	100.00	20.83	100.00

Total number of particles counted: Station N, 13,347; Station O, 13,176.

Number of radioactive particles counted: Station N, 146; Station O, 15.

Percentage of radioactive particles: Station N, 1.09; Station O, 0.11.

Size range, μ	Station R_{ns} a	Station R_{ns} b	Station R_{ns} c	Station S a	Station S b	Station S c
1-2	64.23			54.96		
2-4	80.50			72.49	0.04	3.12
4-6	88.38			82.92		
6-10	92.91			89.86	0.11	6.25
10-15	95.30	1.16	1.16	93.05	0.95	18.75
15-20	96.91	4.65	5.81	95.03	1.55	31.25
20-30	98.29	11.63	17.44	96.90	3.27	56.25
30-40	98.79	5.81	23.25	97.94	2.20	65.62
40-50	99.22	17.44	40.69	98.72	2.94	75.00
50-200	99.85	40.70	81.39	99.64	3.30	87.50
>200	100.00	18.61	100.00	100.00	8.69	100.00

Total number of particles counted: Station R_{ns}, 26,362, Station S, 13,069.

Number of radioactive particles counted: Station R_{ns}, 86; Station S, 32.

Percentages of radioactive particles: Station R_{ns}, 0.33; Station S, 0.24.

Table 6.10 — (Continued)

Size range, μ	Station U a	Station U b	Station U c	Station W a	Station W b	Station W c
1–2	68.41			59.97		
2–4	84.77			76.21		
4–6	91.45			84.85		
6–10	94.73	0.68	3.75	90.42		
10–15	96.43	0.44	5.06	93.29	0.25	1.29
15–20	97.65	2.45	10.12	95.51	1.66	7.79
20–30	98.53	1.69	12.65	97.20	2.62	15.58
30–40	98.92	13.46	21.51	98.06	5.21	23.37
40–50	99.35	15.51	32.91	98.74	17.20	44.15
50–200	99.80	56.66	75.94	99.75	20.58	80.51
> 200	100.00	73.07	100.00	100.00	45.45	100.00

Total number of particles counted: Station U, 13,382; Station W, 13,510.

Number of radioactive particles counted: Station U, 79; Station W, 77.

Percentage of radioactive particles: Station U, 0.59; Station W, 0.57.

Average and totals for Mike shot.

Size range, μ	a	b	c
1–2	62.37		
2–4	78.41	0.008	0.35
4–6	86.73	0.02	0.88
6–10	91.81	0.12	2.66
10–15	94.38	0.42	5.69
15–20	96.31	1.16	11.92
20–30	97.82	1.96	20.10
30–40	98.50	4.01	27.75
40–50	99.06	9.47	42.34
50–200	99.79	19.55	81.85
> 200	100.00	31.77	100.00

Total number of particles counted, 155,731.

Number of radioactive particles counted, 568.

Percentage of radioactive particles, 0.36.

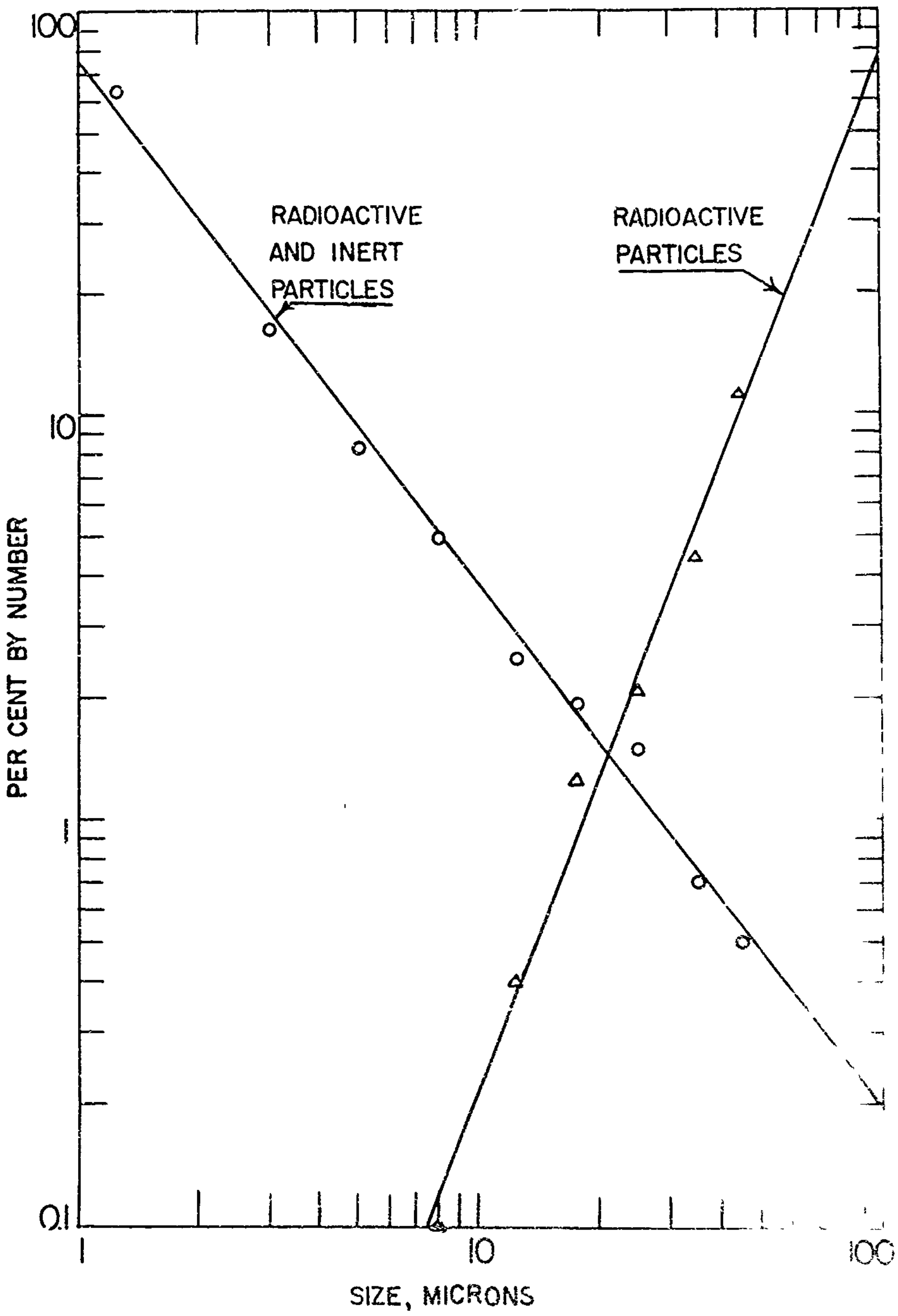


Fig. 6.2—Average percentage of total particles counted in each size range and average percentage of radioactive particles in each size range, Mike shot.

An average of 78 per cent of the total particles counted was 4 μ or less in diameter. Practically none of the particles in this group were radioactive. As the size range increased, the number of particles in each size range decreased. At the same time the percentage of particles in each range which were radioactive increased to the extent that in the range above 200 μ an average of about one particle in three was radioactive.

Disregarding the size ranges, the over-all percentage of particles counted which were radioactive ranged from 0.02 to 1.09 per cent, with a numerical average of 0.36 per cent.

King shot fall-out activities were so low that it was impracticable to determine these percentages.

6.10 PERCENTAGE OF MIKE SHOT TOTAL FALL-OUT WHICH WAS RADIOACTIVE FROM THE GROSS-FALL-OUT COLLECTOR SAMPLES

The percentages of Mike shot total particles counted which were radioactive are shown in Table 6.11 in the same manner as explained in Sec. 6.9.

Gross fall-out at S, U, V, and W stations was heavy enough to enable it to be fractionated by pipetting (Sec. 5.3). The results from each fraction were then recombined into one set of results from each station. Eighty-five to ninety-four per cent of the particles counted were below 4 μ. Very few radioactive particles were in this range. As the size range increased, the percentage of total particles which were radioactive also increased, although the increase in percentage was not consistent (8 to 34 per cent in the 20- to 30-μ range). The over-all percentage of particles which were radioactive varied from 0.20 to 0.39 per cent. Gross-fall-out collector radioactive-particle results at O, P, and R were spoiled by bad film. There was not enough gross fall-out at Y, LL, and MM to be fractionated; so it was analyzed from 2 to 50 μ in a manner similar to the intermittent-fall-out collector counting-cup samples. Eighty-six to eighty-eight per cent of the gross fall-out at Y and LL was 4 μ or below, whereas only 56 per cent of the gross fall-out at MM was in the same size range. As found elsewhere very few radioactive particles were in this size range. The percentage of total particles which were radioactive in each size range increased, as was usual, but the rate of increase at MM was much lower than the rate of increase at the other two stations. The over-all percentage of total particles which were radioactive varied from 0.81 to 2.72 per cent.

The activities from King shot gross-fall-out samples were too low for this analysis.

6.11 INTERMITTENT-FALL-OUT COLLECTOR TOTAL-FALL-OUT PARTICLE ANALYSIS

Several groups of intermittent-fall-out collector total-fall-out slides were selected for analysis. Those slides selected were from stations in the region of radioactive fall-out. Figures C.1 to C.5 show results from Mike shot stations J_s, K, M, N, O, R_s, S, U, and LL_n. Results from King shot J_n, L, N, O, P, R_n, R_s, S, U, W, LL_n, and LL_s stations are shown in Figs. C.6 to C.10.

The nature of the samples obtained and the analytical techniques used limited the size range which could be determined. As mentioned in Sec. 5.4, background limited the lowest size determined to 0.1 μ. The determination of large particles was not limited by background or laboratory techniques. However, unattached large particles (loose in the shipping boxes) indicated that particles larger than about 500 μ were not held in place on the slides by the silicone.

A variety of particle size, particle-size distribution, and concentration parameters were obtained for each sample. The nature and method of obtaining each of the parameters tabulated are as follows:

NMD (number median diameter): A size such that 50 per cent of the particles measured were larger than the NMD, and 50 per cent were smaller; obtained by interpolation of two values nearest 50 per cent on a cumulative graph of the number distribution.

Table 6.11 — SUMMARY OF GROSS-FALL-OUT COLLECTOR RADIOACTIVE- AND TOTAL-PARTICLE-SIZE DATA, MIKE SHOT*

Size range, μ	Station S			Station U		
	a	b	c	a	b	c
< 2	77.38	0.15	35.19	71.47	No radioactive particles were counted owing to film failure	
2–4	93.73			90.78		
4–6	98.48	1.80	78.11	97.20		
6–10	99.44	1.98	87.65	99.29		
10–15	99.75	2.59	91.66	99.76		
15–20	99.89	5.08	95.23	99.92		
20–30	100.00	8.62	100.00	100.00		

Percentages of radioactive particles: Station S, 0.20.

Size range, μ	Station V			Station W		
	a	b	c	a	b	c
< 2	62.92	0.06	6.38	63.42		
2–4	85.87	0.08	11.13	88.03		
4–6	94.44	0.26	16.90	95.97		
6–10	97.50	4.21	50.27	98.93		
10–15	98.75	2.38	57.98	99.54	16.66	51.45
15–20	99.75	7.64	77.77	99.72	12.50	62.84
20–30	100.00	34.33	100.00	100.00	26.21	100.00

Percentages of radioactive particles: Station V, 0.39; Station W, 0.20.

*For an explanation of columns a, b, and c, see Sec. 6.9.

Table 6.11 — (Continued)

Size range, μ	Station Y a	b	c	Station LL a	b	c
< 2	61.60	0.28	21.73	18.73		
2–4	88.33	0.79	47.82	86.44		
4–6	95.83			92.64		
6–10	97.30			97.14	1.40	5.88
10–15	98.49			98.84	12.96	26.47
15–20	98.98	21.43	60.86	99.19	63.64	47.05
20–30	99.61	39.28	86.95	99.75	56.25	76.47
30–40	99.75			99.94	100.00	94.11
40–50	99.86	100.00	100.00	100.00	100.00	100.00
> 50	100.00					

Total number of particles counted: Station Y, 2854; Station LL, 3177.

Number of radioactive particles counted: Station Y, 23; Station LL, 34.

Percentage of radioactive particles: Station Y, 0.81; Station LL, 1.07.

Size range, μ	Station MM a	b	c
< 2	26.87		
2–4	56.64	0.41	4.49
4–6	75.11	0.33	6.74
6–10	85.26	0.60	8.98
10–15	90.43	1.78	12.35
15–20	92.05	11.32	19.10
20–30	96.05	14.78	40.44
30–40	97.55	30.61	57.30
40–50	98.56	45.45	74.15
> 50	100.00	47.92	100.00

Total number of particles counted, 3271.

Number of radioactive particles counted, 89.

Percentage of radioactive particles, 2.72.

D^2MD (surface median diameter): A surface median, similar to, and obtained in the same manner as, the NMD but based on the second moment of the data.

MMD (mass median diameter): A mass-size parameter, similar to, and obtained in the same manner as, the NMD but based on the third moment of the data.

D_{avg} (average diameter): The average diameter of the particles counted, obtained from the formula

$$D_{avg} = \frac{\Sigma D_n}{\Sigma n} \tag{6.3}$$

σg: A measure of size dispersion, a desensitized variable indicating particle-size heterogeneity, obtained from the formula

$$\log \sigma g = \sqrt{\frac{1}{6.9} \log \frac{MMD}{NMD}} \tag{6.4}$$

This value of σg is not the geometric standard deviation of the distribution as counted. It is, in fact, the geometric standard deviation of a logarithmonormal distribution with the same ratio of MMD to NMD, and, since the distributions do not appear to be log-normal (see Sec. 7.9), σg does not indicate the percentage of the particles to be found in a certain size range. The σg tabulated is a coarse measure of the size heterogeneity indicated by the disparity of the median diameters.

No./cm^2: The number of particles of fall-out per square centimeter of slide surface.

s/cm^2: The surface area of particulate fall-out (in square centimeters) per square centimeter of slide surface

v/cm^2: The volume of particulate material (in cubic centimeters) falling out per square centimeter of slide surface.

No./cm^2: 0.1 to 1.0 μ, 1.0 to 10 μ, 10 to 100 μ, 100 μ and up — The number of particles of fall-out per square centimeter in the size range indicated.

In analyzing the samples, it was noted that a number of the parameters, such as D^2MD, MMD, s/cm^2, v/cm^2, No./cm^2 (2 to 10 μ), No./cm^2 (10 to 100 μ), and No./cm^2 (larger than 100 μ), were independent of the electron-microscope portion of the analysis. This fact led to the analysis of approximately 100 samples, for the stated parameters only, by light-optical methods alone. These data are included in Appendix C for each shot.

Some slides at the stations listed were not analyzed. These slides were broken, had a deposit too heavy for analysis, or were from trays which collected no activity.

6.12 PHYSICAL DESCRIPTION OF THE PARTICLES

Particles were generally irregularly spherical. They crumbled easily, and their colors mostly ranged from white to gray. Some dark-brown particles were also noted. The particles were both crystalline and amorphous, and there was no difference in color between the radioactive and the inert particles. The average density of the gross-fall-out samples was 2.6 g/cm^3.

6.13 MIKE SHOT RADIOCHEMICAL ANALYSES

All radiochemical data have been corrected to zero time. Data for the liquid fall-out are presented as counts per minute per milliliter in Table 6.12. Data for the solid fall-out are tabulated as counts per minute per milligram in Table 6.13. It may be noted that there appear to be three general types of relations between activity and particle size: (1) constant, (2) max-

Table 6.12—SPECIFIC ACTIVITIES AT ZERO TIME FOR LIQUID FALL-OUT, MIKE SHOT*

Station	Sr^{89} ($\times 10^{-2}$)	Zr^{95}	Mo^{99} ($\times 10^{-4}$)	Ru^{103}	Ru^{106}	Ba^{140} ($\times 10^{-3}$)	Ce^{144}
S	2.76	3.7	8.33	19.5	1.6	4.24	2.4
U	0.96	8.5	3.49			0.955	2.0
MM	2.80	14	5.49	8.6	1.0	3.38	8.3

*Activity is given in counts per minute per milliliter.

Table 6.13—SPECIFIC ACTIVITIES AT ZERO TIME FOR SOLID FALL-OUT, MIKE SHOT*

Station	Mean particle size, μ	Sr^{89} ($\times 10^{-2}$)	Zr^{95} ($\times 10^{-2}$)	Mo^{99} ($\times 10^{-4}$)	Ru^{103} ($\times 10^{-3}$)	Ru^{106} ($\times 10^{-2}$)	Ba^{140} ($\times 10^{-3}$)	Ce^{144} ($\times 10^{-2}$)
O	77	9.16	30.6				19	
	105	0.910	19.1					11.3
	125	2.22	24.8					15.9
	150	4.24	14.2					13.1
	212	3.28	2.91				4.8	3.13
S	77	4.05		5.39	0.13	6.50	13.3	9.76
	105	5.0		9.3			12.4	
	125	3.34	11.0	5.6	6.88	8.21	9.87	7.26
	150	3.14	9.85	5.41	4.91	8.11	8.85	26.4
	212	1.76	5.48	3.29	3.66	5.19	5.03	9.19
U	77	3.3		6.6			7.83	6.00
	105	3.1	3.30		4.46	5.35	8.1	5.70
	125	2.69		2.7			7.19	4.61
	150	1.52	1.52	1.8	7.20	7.99	5.47	2.41
	212	0.85	1.40	0.734			2.03	1.29
MM	77	3.72		7.37			5.56	
	105	3.7		7.5	8.60	4.30		
	125	3.20		5.47	1.35	1.80	6.47	8.79
	150	4.02	52.6	7.78	9.32	1.00	9.08	13.3
	212	3.60	25.2	8.2			13.6	19.0

*Activity is given in counts per minute per milligram.

imum at about 100 μ, and (3) minimum at about 100 μ. The situation is complicated by the strong evidence that activity was deposited on the particles from solution.

In accordance with the usual conventions, R factors with respect to Mo^{99} and Zr^{95} are given in Tables 6.14 through 6.16. The R factor is defined as

$$R = \frac{(A/B)_{shot}}{(A/B)_{pile}} \tag{6.5}$$

where A and B are the counts per minute from any two stations.

In this manner the work of different laboratories may be directly compared. For this work the pile figures were obtained by a thermal-neutron bombardment of U^{235} in the Brookhaven reactor.

An examination of the R factors indicated the likelihood of a peculiar fractionation of activities between the liquid and solid phases. This phenomenon was verified by the data of Table 6.17, which were calculated in the following manner: the liquid depths were measured in the field and found to be 3 in. at S and 2 in. at U. By means of the formula

$$V = (2.54 \times 10^{-2})h^3 + 5.15h^2 + (3.46 \times 10^2)h \tag{6.6}$$

which is derived in Appendix D, the liquid columns were calculated to be 17.7 liters at S and 11.6 liters at U. From S 590 ml and from U 685 ml were each diluted to 1 liter for analysis. From these figures the total counts per minute in each liquid sample were estimated.

The solid fall-out weighed 14.4 g at S and 9.8 g at U. Average counts per minute per milligram were calculated from the data of Table 6.13. (Note the very questionable assumption that these averages are valid for the total sample.) From these figures the total counts per minute in each solid sample were estimated. The liquid-to-solid ratios were then obtained directly.

Although the data of Table 6.17 are given to two significant figures, they are probably not accurate to more than one because of the assumptions made and the rough nature of the field measurements. However, the data assume considerable significance where they differ by orders of magnitude.

It should be noted that the average particle size of the gross-fall-out fractions published in the preliminary report of this project[20] was in error by a factor of 1.3.

It is of special interest that most of the Mo^{99} appeared in the liquid phase. Furthermore, substantial fractions of the Ba^{140} and Sr^{89} were in solution.

The liquid phases of the total-fall-out samples from S and U gave negative or slight chloride-ion tests, whereas the liquid phase at MM gave a definitely positive chloride-ion test. This is not surprising since MM is approximately 20 ft above the surface of the lagoon. The presence of calcium ions was indicated in the liquid phases from all the above-mentioned stations by the precipitation of CaC_2O_4. The pH of the liquid phase ranged from 7.9 at MM to 10.2 at U. The liquid from S was excluded in the pH measurements because HNO_3 had been added. Since the pH of the other three solutions decreased with time and since a white precipitate settled out of all the liquid phases after a few weeks, the presence of $Ca(OH)_2$ is suspected. Nitrate ion in concentrations less than $10^{-3}M$ was indicated by the diphenylamine test.

Table 6.14—R FACTORS OF COUNTING-RATE RATIOS TO Mo^{99} FOR LIQUID FALL-OUT, MIKE SHOT*

Station	Sr^{89}	Zr^{95}	Ru^{103}	Ru^{106}	Ba^{140}	Ce^{144}
S	30.9	0.37	2.3	1.1	102	0.94
U	26	2.0			55.0	2.0
MM	47.6	2.1	1.5	1.0	124	5.1

*The R factors are given in units $\times 10^3$.

Table 6.15—R FACTORS OF COUNTING-RATE RATIOS TO Mo^{99} FOR SOLID FALL-OUT, MIKE SHOT

Station	Particle size, μ	Sr^{89}	Zr^{95}	Ru^{103}	Ru^{106}	Ba^{140}	Ce^{144}
S	77	0.200		3.07	19.0	1.38	1.7
	105	0.14				0.749	
	125	0.155	0.44	3.34	23.1	0.984	1.23
	150	0.150	0.422	2.47	23.6	0.911	4.59
	212	0.139	0.385	3.97	32.5	0.855	2.63
U	77	0.13				0.671	0.86
	105						
	125	0.25		1.32	10	1.45	1.6
	150	0.23	0.20	1.5	9.3	1.01	1.3
	212	0.299	0.42			1.6	1.7
MM	77	0.131				0.421	
	105	0.12		1.6	11		
	125	0.152				0.660	1.52
	150	0.134	1.57	2.52	16.2	0.654	1.61
	212	0.113	0.70			0.917	2.2

Table 6.16 — R FACTORS OF COUNTING-RATE RATIOS TO Zr^{95} FOR SOLID FALL-OUT, MIKE SHOT

Station	Particle size, μ	Sr^{89}	Ru^{103}	Ru^{106}	Ba^{140}	Ce^{144}
O	77	0.248			0.15	
	105	0.0394				2.42
	125	0.0739				2.61
	150	0.247				3.75
	212	0.934			0.67	4.40
S	77					
	105					
	125	0.35	7.6	52	2.2	2.8
	150	0.355	5.85	55.9	2.16	10.9
	212	0.361	10.3	84.4	2.22	6.83
U	77					
	105	1.0	30	88	5.8	6.9
	125					
	150	1.2	7.5	46	5.0	6.5
	212	0.71			3.8	4.0
MM	77					
	105					
	125					
	150	0.0854	1.60	10.3	0.46	1.02
	212	0.16			1.3	3.1

Table 6.17 — FRACTIONATION OF FALL-OUT ACTIVITIES BETWEEN LIQUID AND SOLID, MIKE SHOT

	Station	Sr^{89}	Zr^{95}	Mo^{99}	Ru^{103}	Ru^{106}	Ba^{140}	Ce^{144}
Total counts/min of liquid	S	8.3×10^6	1.1×10^5	2.5×10^9	5.8×10^5	4.8×10^4	1.3×10^8	7.2×10^4
Total counts/min of solid		5.0×10^6	1.3×10^7	8.4×10^8	7.8×10^7	1.0×10^7	1.4×10^8	1.9×10^7
Liquid-to-solid ratio		1.7	0.0088	3.0	0.0075	0.0048	0.89	0.0038
Total counts/min of liquid	U	1.6×10^6	1.4×10^5	5.9×10^8			1.6×10^7	3.4×10^4
Total counts/min of solid		2.2×10^6	2.0×10^6	2.9×10^8	5.7×10^7	6.5×10^6	6.0×10^7	3.9×10^6
Liquid-to-solid ratio		0.73	0.070	2.0			0.27	0.0087

CHAPTER 7

DISCUSSION

7.1 ACTIVITY MEASUREMENTS

The statistical-counting accuracy of the activity measurements was limited by practical considerations which have been described in Sec. 5.1. However, the accuracy is enough to show the random nature of fall-out in a small area, which is probably due to varying and changeable weather conditions. The activities reported here do indicate the order of magnitude of the radioactive fall-out at a particular station.

It would be desirable to sample a larger area of fall-out at a given station to obtain more information on the random nature of fall-out. For Mike shot two intermittent-fall-out collectors were placed about 10 ft apart at eight stations; however, five of the eight stations either did not operate or were outside the area of fall-out. The averaged results at J_{ns} and R_{ns} were apparently less random than results at most individual stations in the same areas. The averaged results at LL_{ns} are quite random; however, the intensity of fall-out was much less at these stations.

Activity data from the Mike L station are probably not so accurate as activity results from the other stations. Some time after tray 2 had sampled, a driving chain came off its sprockets It is unknown whether the activities reported for Mike are from (1) actual fall-out during the proper sampling interval, (2) the result of a loose gasket between the top cover and the tray in sampling position, or (3) a combination of both.

Activity and particle-size data from tray 24 are not so meaningful and reliable as most of the data from the other trays. Tray 24 was positioned under the sampling opening in the cover both before and after the 6-hr sampling period. The cover door did not always fit tightly and sometimes did not close properly. Radioactive and inert dust and water may have been deposited on the slides and in the cups before and after the regular 15-min sampling period had been completed.

7.2 VARIATION OF ACTIVITY WITH DISTANCE SOUTHEAST OF MIKE SHOT GROUND ZERO

Figures 7.1 through 7.6 represent graphically the variation of activity with distance based upon the intermittent-fall-out collector counting-cup samples.

Initial activities in the counting cups varied from 10^{12} to 10^{13} dis/min during the first sampling period, $\frac{1}{4}$ to $\frac{1}{2}$ hr after shot time. Activity peaks decreased to about 10^{12} dis/min from $\frac{1}{2}$ to $2\frac{1}{4}$ hr, 10^{11} dis/min from $2\frac{1}{4}$ to $3\frac{3}{4}$ hr, 10^{10} dis/min from $3\frac{3}{4}$ to $4\frac{1}{2}$ hr, and 10^{9} dis/min from $4\frac{1}{2}$ to 6 hr after shot time. The rise to 10^{10} dis/min from 6 to $6\frac{1}{4}$ hr (tray 24) is probably due to the radioactive fall-out being sampled at 15 min after shot time while the intermittent-fall-out collector is in the process of opening. Minimum sample activities during the 6 hr usually did not go below 10^{7} dis/min during the entire sampling period.

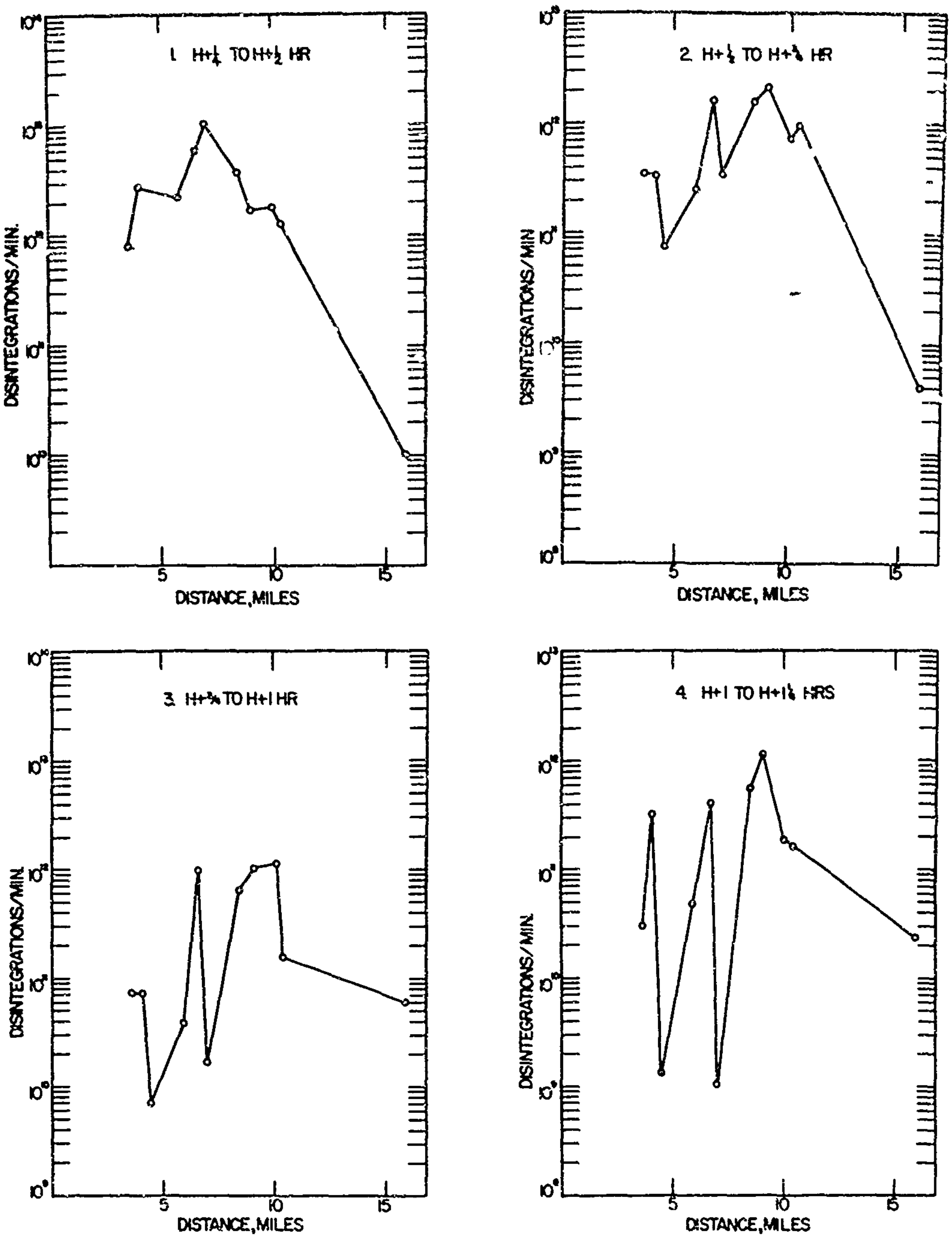


Fig. 7.1—Mike shot variation of activity with distance from H + ¼ to H + 1¼ hr.

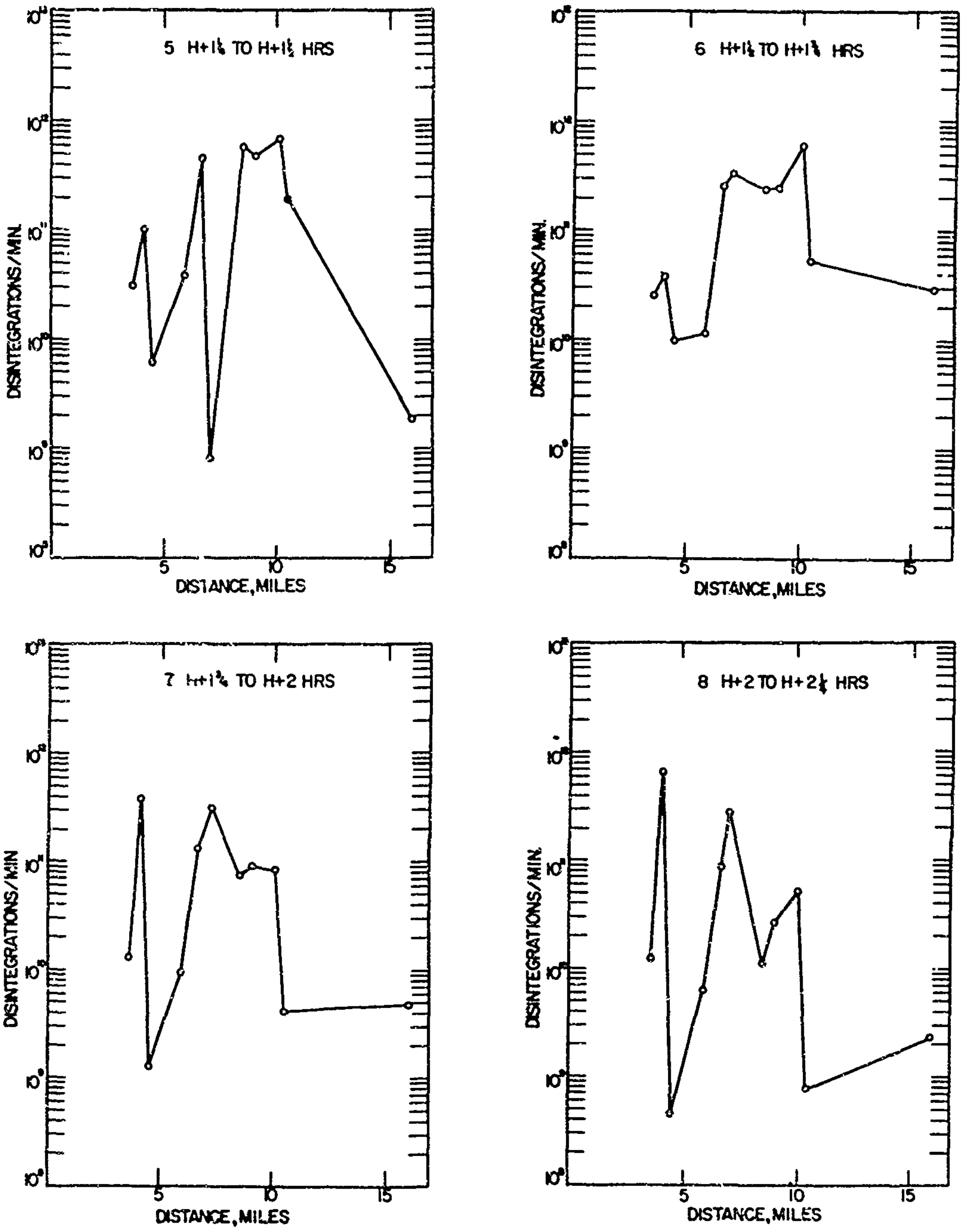


Fig. 7.2—Mike shot variation of activity with distance from H + 1¼ to H + 2¼ hr.

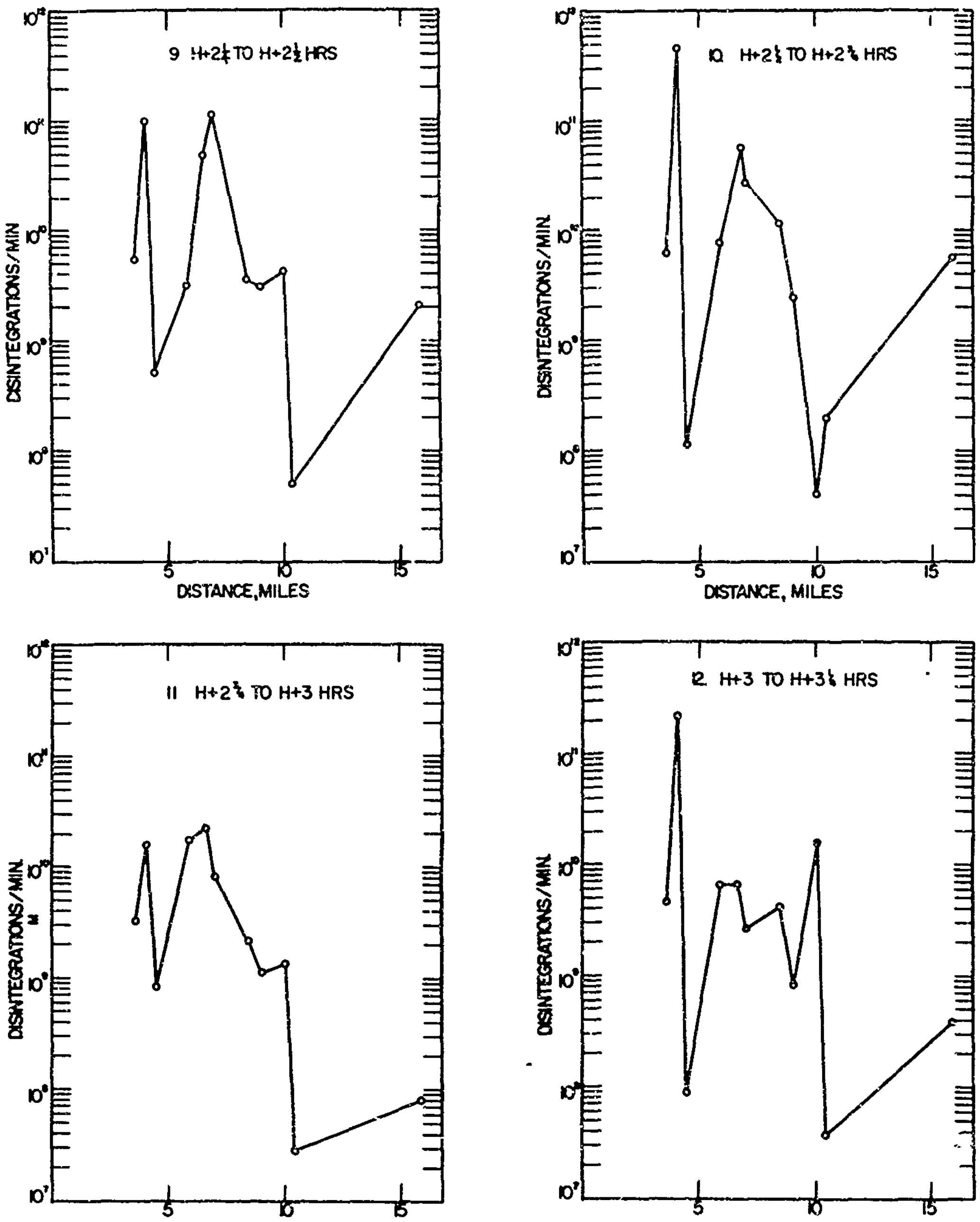


Fig. 7.3—Mike shot variation of activity with distance from H + 2¼ to H + 3¼ hr.

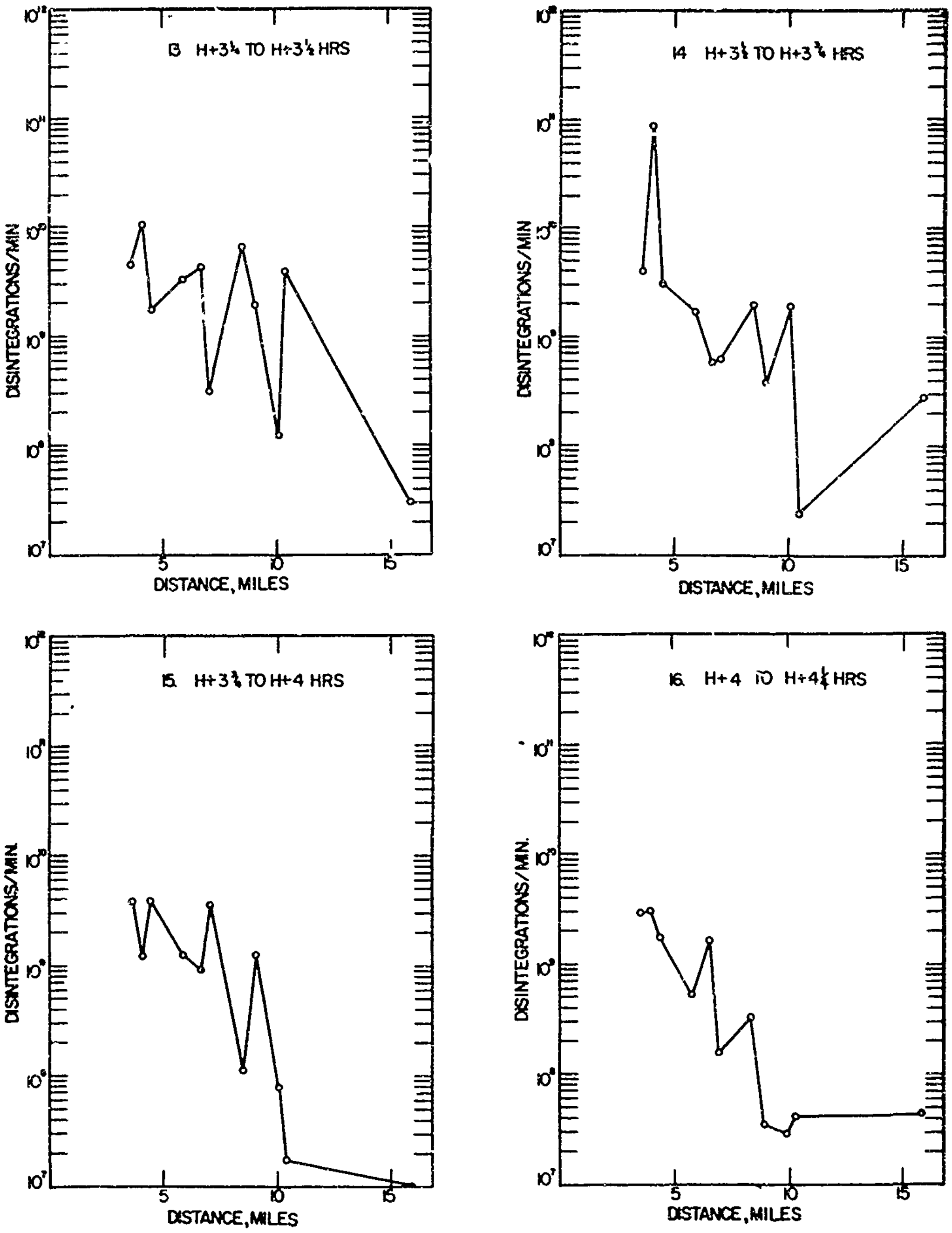


Fig. 7.4—Mike shot variation of activity with distance from H + 3¼ to H + 4¼ hr.

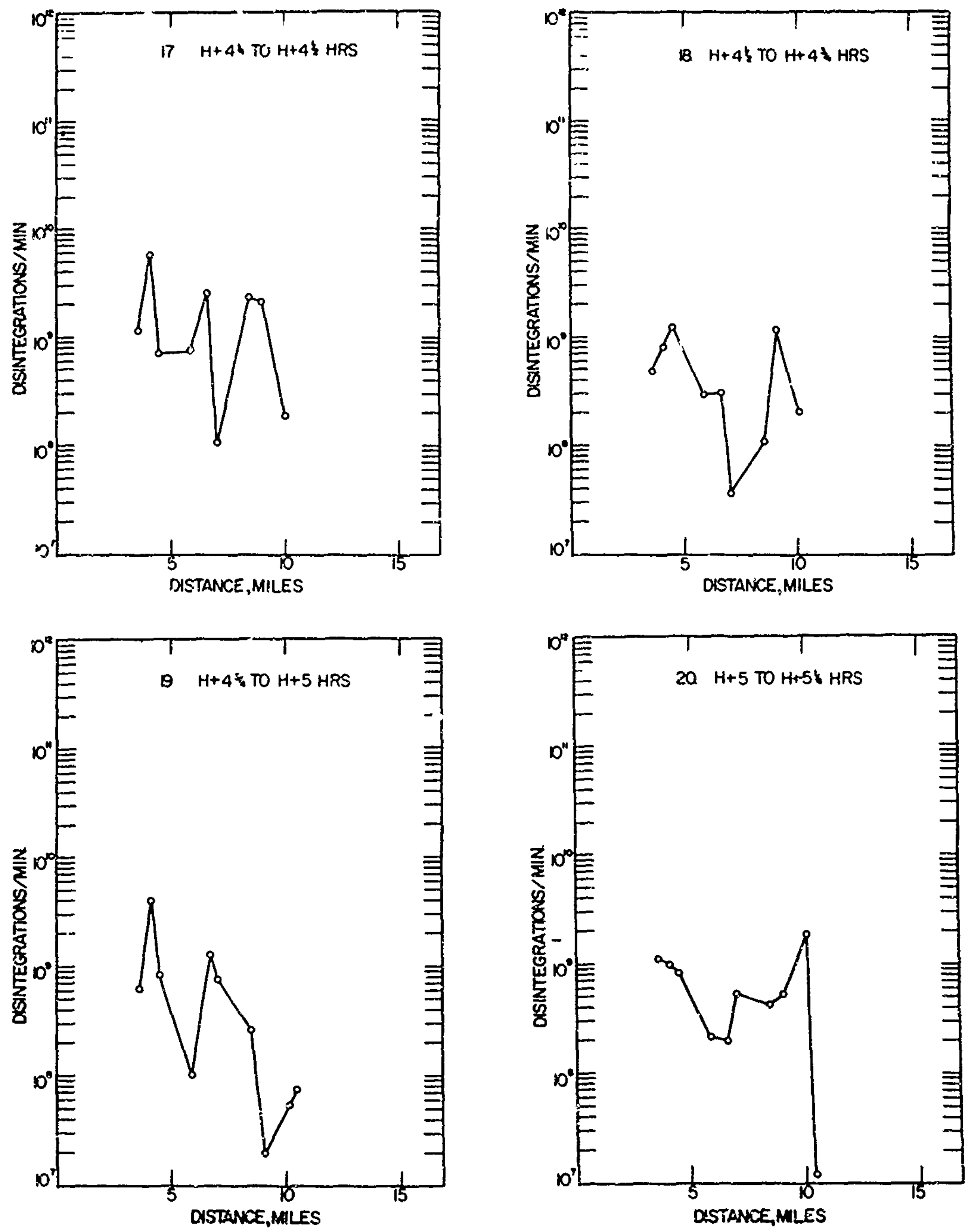


Fig. 7.5—Mike shot variation of activity with distance from H + 4¼ to H + 5¼ hr.

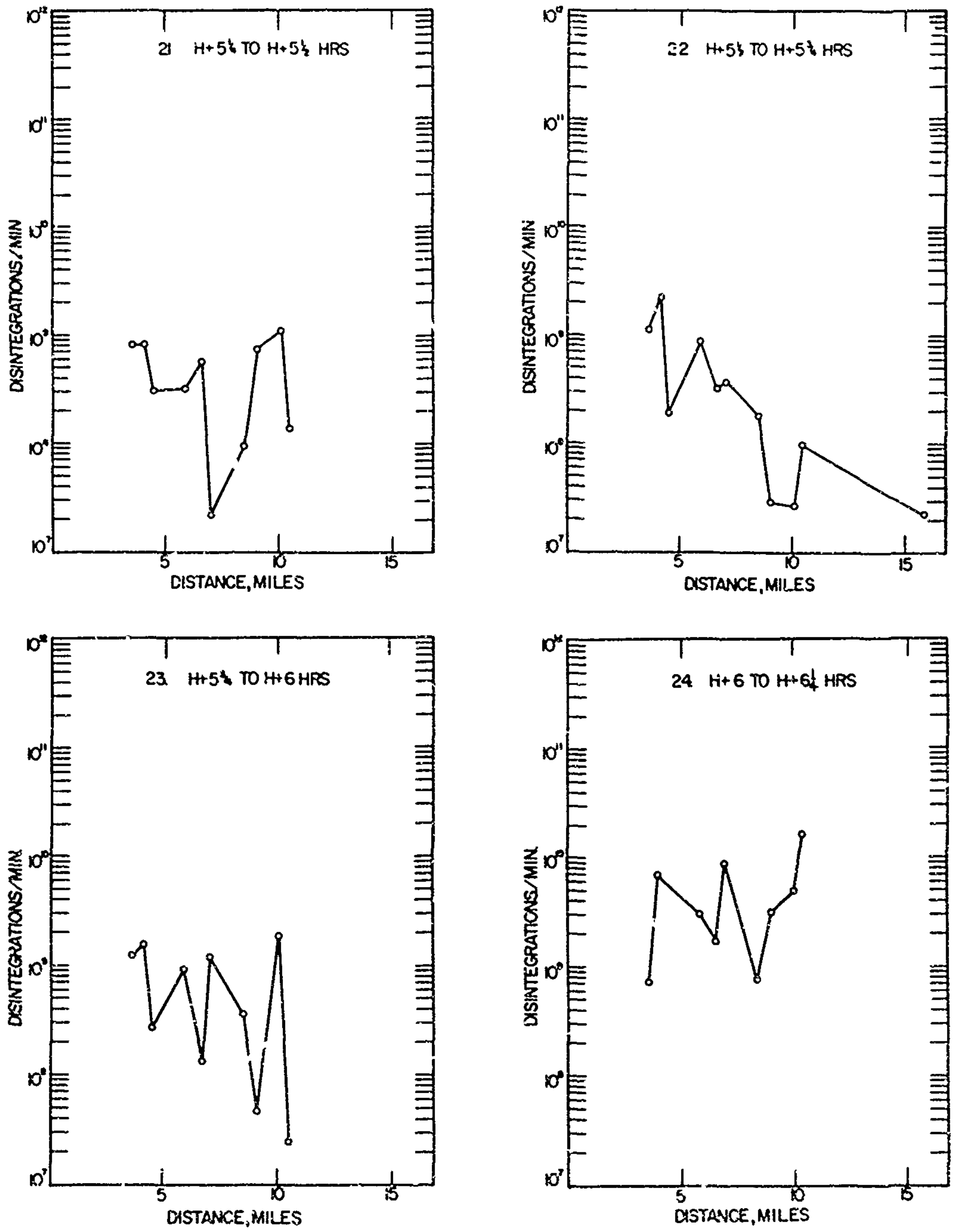


Fig. 7.6—Mike shot variation of activity with distance from H + $5^1/_4$ to H + $6^1/_4$ hr.

The initial peak of radioactive fall-out, 15 to 30 min after sampling time, occurred 7 miles from ground zero and moved 9 to 10 miles from ground zero during the first $1\frac{3}{4}$ hr. A secondary peak appeared $\frac{1}{2}$ hr after shot time about $6\frac{1}{2}$ to 7 miles from ground zero and continued until 3 hr after shot time. Another secondary peak appeared 4 miles from ground zero 1 hr after shot time. Fall-out in these areas continued for most of the remaining sampling period.

Other secondary peaks of activity occurred randomly 7 to 10 miles from ground zero during the last 3 hr of sampling. Deposition of fall-out during the first 2 or 3 hr after shot time was probably less influenced by weather conditions than the deposition of later fall-out.

It is interesting to note that, except for the periods $3\frac{3}{4}$ to $4\frac{1}{4}$ hr and 5 to $5\frac{1}{4}$ hr after shot time, activity levels at J station are significantly lower than the peak activities of other stations during the same time interval.

Fall-out activities from GG were so low that they were not recorded on the activity-vs-distance graphs.

7.3 VARIATION OF ACTIVITY WITH TIME, MIKE SHOT

Figures 7.7 through 7.9 represent the variation of activity with time based on the intermittent-fall-out collector counting-cup samples.

The most radioactive fall-out from Mike shot arrived at all stations less than 30 min after shot time, except at LL, where it occurred $\frac{3}{4}$ to 1 hr after shot time. LL was south-southwest from Mike shot ground zero, whereas all the other stations were generally southeast from ground zero. The heaviest radioactive fall-out on Operation Jangle also occurred within a short time after each detonation.[11] There would appear to be an external radiation hazard to personnel remaining in the areas of highly radioactive fall-out during the first few hours after the Mike detonation.

Activities decreased fairly regularly with time at J and R, although, during the last 2 to 3 hr, the radioactive fall-out appeared to be more random than it had been earlier. Stations J_{as} and R_{as} are averages of activities of two individual collectors, which may be the cause of the regularity. Secondary peaks arrived at K, L, and M from 2 to 4 hr after shot time and at N about $4\frac{1}{2}$ hr after shot time. M also had a small peak at $5\frac{1}{2}$ to 6 hr. Station O had a very high secondary peak $2\frac{1}{2}$ to $3\frac{1}{4}$ hr after shot time and small peaks at $3\frac{3}{4}$ and $5\frac{3}{4}$ hr after shot time. R had a small peak at $3\frac{1}{4}$ to $3\frac{1}{2}$ hr. Fall-out at S, U, and W became quite sporadic after about 3 hr. Activities at these three stations are generally slightly higher toward the end of the sampling period than the activities about midway through the sampling period. Measurable radioactive fall-out did not occur at GG except from $2\frac{1}{4}$ to $3\frac{1}{4}$ hr and $5\frac{1}{2}$ to 6 hr after shot time.

Activities from tray 24 are not necessarily indicative of the fall-out during 6 to $6\frac{1}{4}$ hr after shot time. When the intermittent-fall-out collector cover door opens, the spider is in the process of moving tray 24 from under the cover opening and moving tray 1 in its place; hence, a small amount of early fall-out may have been deposited in tray 24.

7.4 VARIATION OF ACTIVITY WITH TIME AND DISTANCE, KING SHOT

Stations 3 to 4 miles northwest of ground zero, the closest operating stations, received fall-out during very few time intervals. Radioactive fall-out was deposited over a majority of the sampling time at stations 5 to 5.6 miles northwest of ground zero. Practically no activity was found at N and P, 6.2 and 7.2 miles from ground zero, but O, 7 miles from ground zero, recorded small amounts of activity during most of the first 5 hr. The stations 7.7 to 10 miles northwest of ground zero sampled radioactive fall-out during the entire sampling period.

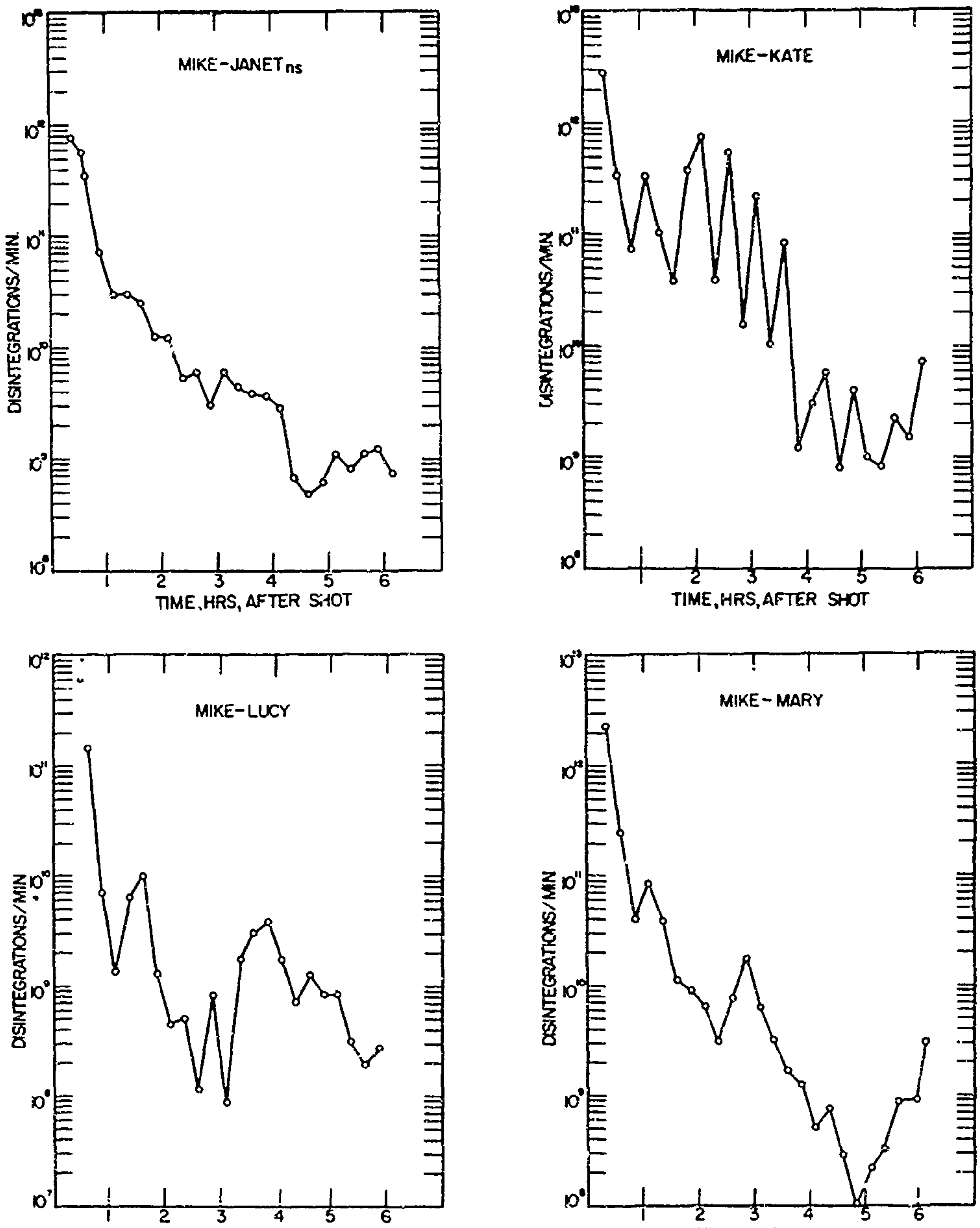


Fig. 7.7—Mike shot variation of activity with time, stations I_{ns}, K, L, and M.

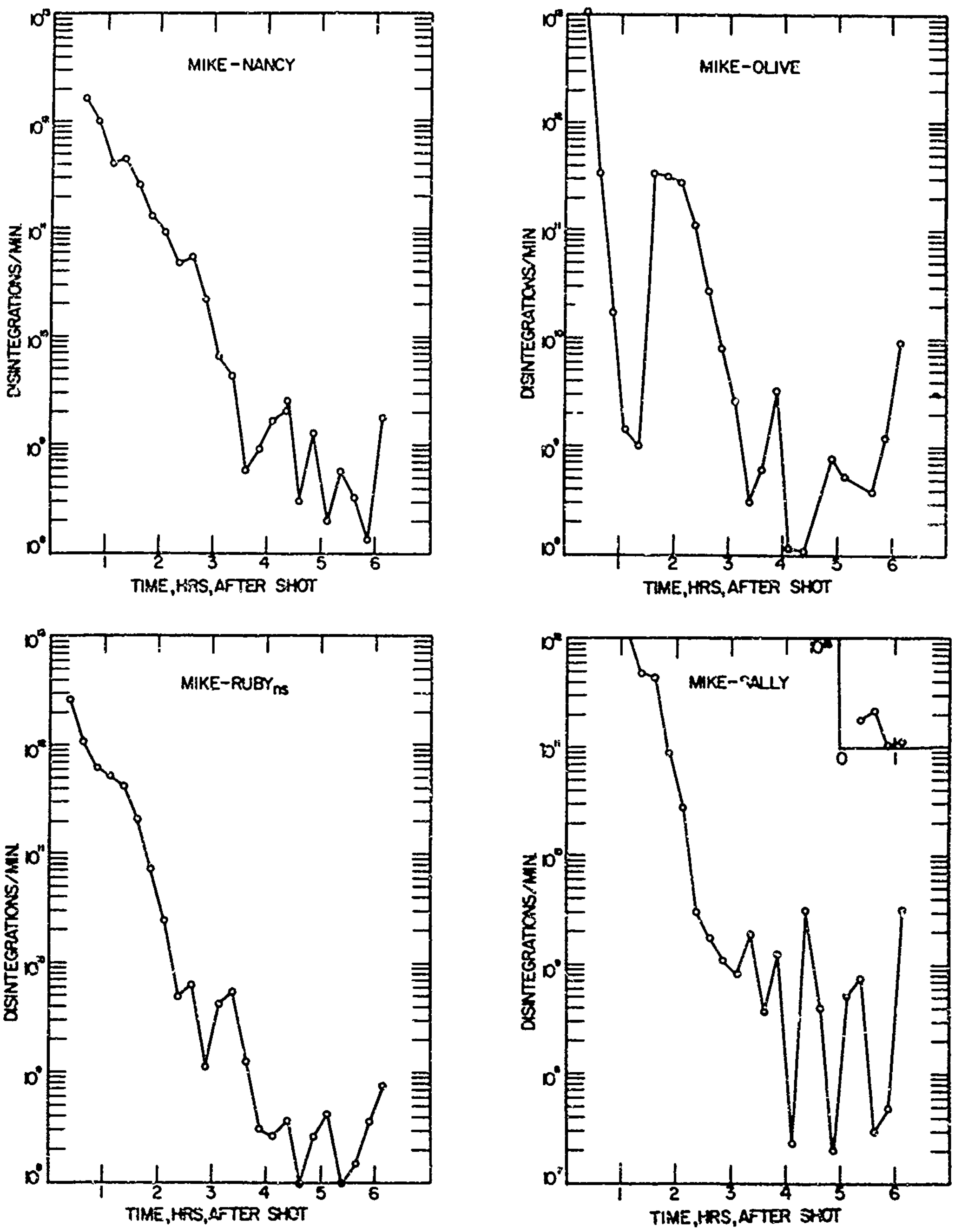


Fig. 7.8—Mike shot variation of activity with time, stations N, O, R_{ns}, and S.

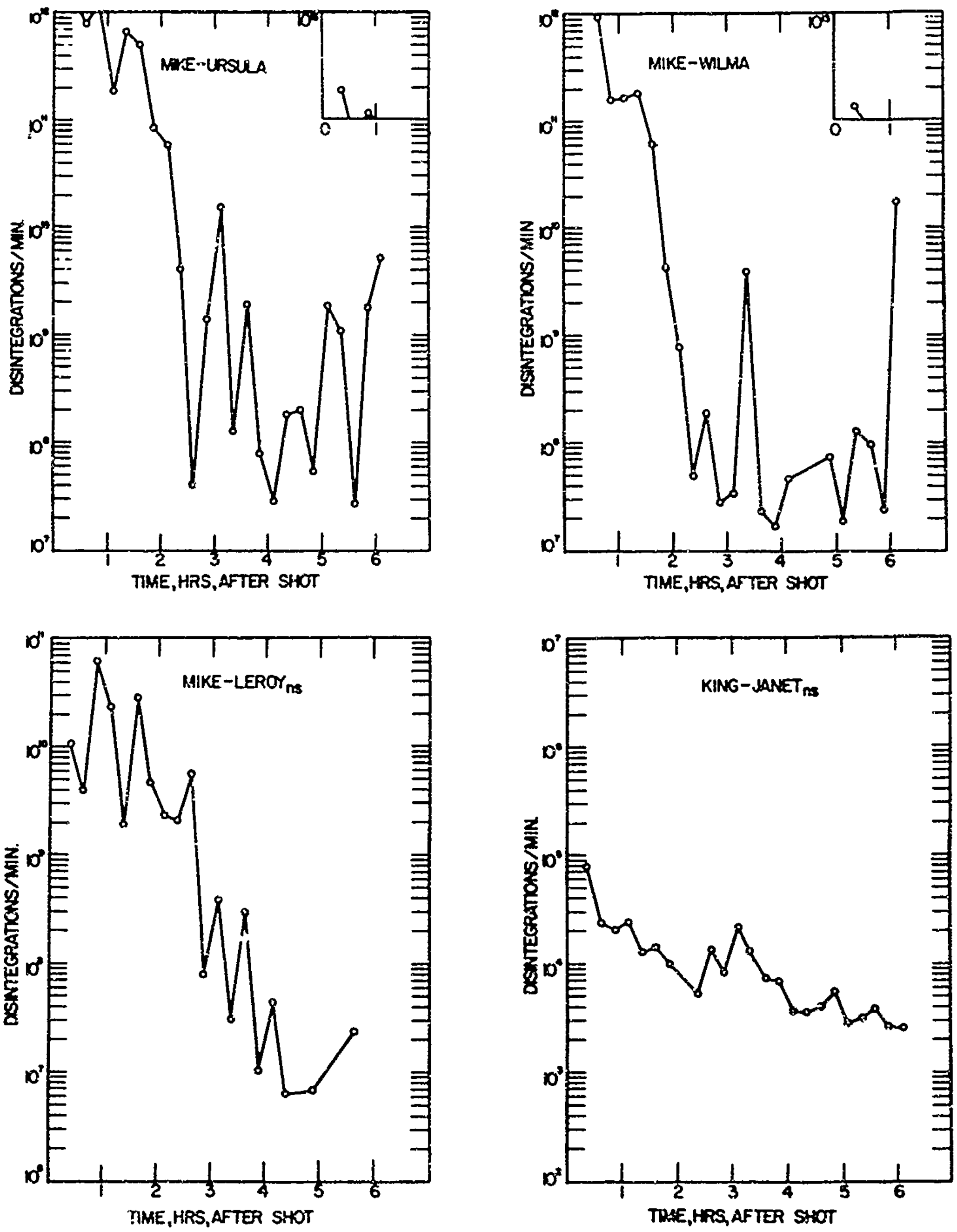


Fig. 7.9—Variation of activity with time, Mike shot, stations U, W, and LL$_{ns}$; King shot, Station J$_{ns}$.

Maximum activities occurred during the first 30 min in the area of continuous fall-out at J (Fig. 7.9), K, L, and M, 7.7 to 10 miles from ground zero, and also at R, 5.6 miles from ground zero. A secondary peak appeared $2\frac{1}{2}$ to $2\frac{3}{4}$ hr after shot time at R. A secondary peak occurred 3 to $3\frac{1}{4}$ hr after shot time at J. A secondary peak appeared $4\frac{3}{4}$ to 5 hr after shot time and also at the end of the sampling period at K. Peak activities at stations which collected sparse fall-out showed no trend with time.

7.5 EFFECT OF WINDS ON FALL-OUT DEPOSITION

Wind data, up to altitudes of 90,000 ft, were calculated $6\frac{1}{4}$ hr before Mike shot. From wind vectors drawn from the data, it appeared that a particle originating at any altitude from 65,000 to 90,000 ft directly above ground zero would reach sea level somewhere west of ground zero. Particles originating at altitudes below 60,000 ft above ground zero would reach sea level in the region generally north of Eniwetok Atoll, but the particles would not fall in the Atoll area itself. Actually the cloud and the particles in it spread laterally while they are ascending; hence, only a fraction of the fall-out would start from a point directly above zero. If the cloud had spread enough to have a radius of 10 miles, a 150-μ particle beginning to descend from 20,000 ft at the southeast edge would be deposited along the island chain from J to W. Particles descending from 60,000 to 65,000 ft would be deposited at N and O. It is assumed that most of the particulate matter not in the southern half of the cloud was carried out to sea. No wind data were available for the King shot cloud.

7.6 DECAY MEASUREMENTS FROM INTERMITTENT-FALL-OUT COLLECTOR SAMPLES

The large number of individual decay slopes were run in order to determine if there is any relation between decay slope and either the distance from ground zero or the time after the detonation; there apparently is none. The significant difference between decay slopes is between shots. These average slopes are much different from those ordinarily found from fission products after an atomic device has been detonated. The reason for the differences is not known at this time. Whether there was any relation between the decay slope and the direction from ground zero cannot be shown here since most of the decay data were from stations which were generally southeast from Mike shot ground zero and northwest from King shot ground zero.

Unfortunately no facilities for measuring early decay were set up; hence the correction of activities back to the actual time of sampling necessitated an extrapolation of the available decay data.

7.7 DECAY SLOPES FROM FRACTIONATED GROSS FALL-OUT, MIKE SHOT

From the limited data in Table 6.8, it appears that the half life of gross fission products decreases as the fractionated particle size becomes larger. This trend is the reverse of the trend noted on Operation Jangle and should be investigated further at future atomic weapons tests.

7.8 PERCENTAGE OF MIKE SHOT TOTAL FALL-OUT WHICH WAS RADIOACTIVE FROM INTERMITTENT-FALL-OUT COLLECTOR SAMPLES

The results are based on particle analysis by light microscope and by radioautographic methods. The light microscope precludes the counting of particles much below 1 μ in diameter. Also contrast radioautography, as used, had limitations. At best, exposure time is a compromise; a great variety of activities may be expected with a sample of gross fission products;

therefore exposure time must be short enough so that most active particles can be seen. At the same time the low specific activity or small-area contaminations may not have had any effect since each silver grain of the emulsion must be activated by several beta particles. Also the size of the silver grains is about 0.3 μ, and they are usually 2 μ or more apart. In addition, the celluloid backing undoubtedly absorbed some radiation. Thus by this method it appears that the designation of a particle as radioactive or inert is arbitrary and is less valid for small particles of the order of a few microns. However, no better method for determination of individual particle activity is known.

The radioautographs were not exposed until 30 to 45 days after the Mike detonation. By that time some of the radionuclides had decayed to their inert states. Because of the radioautographic limitations these ratios must be considered low compared to the ratios at the time of sampling. It was not possible with this method of analysis to show a trend of ratios with the time of sampling; therefore the results from one station are grouped together.

From the data obtained it appears that there is little internal hazard from most of these solid radioactive particles.

The very small number of radioactive particles found at L supports the contention that the fall-out collector did not operate after the first few trays. Only two radioactive particles were found, and none were found in the upper two size ranges, whereas every other station shown had radioactive particles in those two ranges.

7.9 PERCENTAGE OF MIKE SHOT TOTAL FALL-OUT WHICH WAS RADIOACTIVE FROM THE GROSS-FALL-OUT COLLECTOR SAMPLES

The limitations of these percentages are the same as the limitations of the ratios found with intermittent-fall-out collector samples, and these ratios must be considered low.

The results from MM station are interesting. Station MM was a platform for a photographic tower in the lagoon which was left from a previous operation. The cumulative percentage of particles under 4 μ was 30 to 37 per cent less than those from other gross-fall-out stations. Probably, as a result, the percentages of particles in the upper size ranges are several times as large as those found at the other stations. Also the percentage of the total number of particles which were radioactive is higher than the percentage at any other station. However, it should be noted that the MM gross-fall-out collector sample was not recovered until K – 3 days.

7.10 INTERMITTENT-FALL-OUT COLLECTOR TOTAL-FALL-OUT PARTICLE ANALYSIS

The NMD at Mike shot J_8 and K stations ranged between 0.2 and 0.3 μ throughout the 6-hr sampling period. The NMD at the other Mike and King shot stations which were analyzed usually ranged between 0.1 and 0.2 μ. The average diameters at Mike J_8 and K were generally slightly above those from the more distant stations sampling during Mike shot. These larger diameters indicated that the fall-out at the closer stations contained larger particles than the fall-out at the more distant stations, as would be expected. No definite trends of particle characteristics with time after shot were found. It is possible that a trend would have been noted if the sampling had extended over a longer period of time.

There were very few trends of particle number vs distance. Stations J_8 and K had a slightly higher number of particles per square centimeter than did the other stations. At these two stations the number of particles per square centimeter in the range 1 to 10 μ was of the order of 10 times the number per square centimeter found at most other stations. The particles deposited were extremely heterogeneous. Generally 90 to 99 per cent of the particles found were less than 1 μ in diameter.

Analysis of airborne particulate material on previous atomic weapons tests has usually led to particle-size distribution curves which were at least approximately logarithmonornal.[9,18,19]

The fall-out material analyzed here did not even approximate such a distribution (lines drawn to fit the calculated σg values did not represent the trend of the data), and no attempt has been made to represent the particle-size distributions by log-probability graphs. Attempts to represent the data as a sum of log-normal distributions, similar to the method suggested by Kottler,[21] were made. It was found impossible to adequately represent the data by less than three log-normal distributions, requiring eight constants to describe each sample. No consistent correlation between any of the particle-analysis parameters and the sample numbers (function of time) could be found, and thus it is inferred that it is not possible to differentiate test effects from random background fall-out on the basis of total-particle analysis alone.

7.11 FUTURE STUDIES

Since Mike shot was a different type of detonation than that at any previous operation, projects are underway to determine (1) additional radiochemical properties and (2) methods of association of activity with the radioactive particles.

CHAPTER 8

CONCLUSIONS

The conclusions reached are those based upon data from land stations at the Atoll. No conclusions can be made in regard to fall-out over any of the water areas since they are beyond the scope of this project.

8.1 MIKE SHOT

Activities found from intermittent-fall-out collector samples 0.54 sq in. in area ranged from 10^9 to 10^{13} dis/min. Upon conversion to curies per square foot these activities ranged up to 2750 curies/sq ft on the initial samples. Mike shot radioactive fall-out occurred as far as 15 miles upwind (southeast) from ground zero. The maximum quantity of fall-out usually occurred during the first 30 min after detonation. The fall-out continued for at least 6 hr after the detonation within the 15-mile range. Light radioactive fall-out was also found 16 miles south-southwest of ground zero. No radioactive fall-out was found at island stations 19 to 24 miles southeast to south-southeast from ground zero.

During the first sampling interval, from $\frac{1}{4}$ to $\frac{1}{2}$ hr after shot time, the largest amount of radioactive fall-out occurred at the station $6\frac{1}{2}$ miles from ground zero. In general, the stations 6 to 10 miles from ground zero received the heavier fall-out until $1\frac{3}{4}$ hr after shot time. From then on the heavier fall-out occurred at the stations closer to ground zero, about $3\frac{1}{2}$ to 6 miles away, until about 5 hr after shot time. From then until the end of sampling time, fall-out was apparently random.

By electron-microscope, light-microscope, and viewer analysis, generally over 90 per cent of the particles in the intermittent-fall-out collector samples from the area in which radioactive fall-out occurred were less than 1 μ in diameter. About 94 per cent of the radioactive particles which were found were larger than 10 μ. No trend of particle size with time of sampling was found. On an over-all basis 0.36 per cent of the Mike shot intermittent-fall-out collector particles, counted by light microscope only, were radioactive. On the basis of these data, these solid particles constitute only a small internal radiological respiratory hazard.

The average Mike shot decay slope for all stations is -2.1 for the period of M + 100 to M + 500 hr. There is no decay slope trend with either time or distance, but a trend with particle size has been indicated.

There was fall-out of liquid from the Mike shot cloud.

8.2 KING SHOT

Activities of King shot intermittent-fall-out collector samples were lower by a factor of 10^3 to 10^5 than those found from Mike shot. These activities ranged up to 9.2×10^{-4} curies/sq ft,

based on activities from initial samples. Relatively small amounts of fall-out occurred as far as 10 miles northwest of ground zero. Radioactive fall-out continued during the entire sampling period at stations 7.7 to 10 miles northwest of ground zero and during most of the sampling period at stations 5 to 5.6 miles northwest of ground zero. Very little radioactive fall-out occurred at the closest stations and at stations 6 to 7 miles northwest of ground zero. No radioactive fall-out was found at stations 6 to 14 miles south-southeast and south of King shot ground zero.

The average King shot decay slope for all stations for the period of K + 150 to K + 450 hr was −0.65. As with the Mike shot decay slopes, there was no trend of slopes with time after the shot or distance from ground zero.

There is little external hazard from fall-out due to air bursts detonated at a scaled height equal to or higher than that of the King shot blast.

CHAPTER 9

RECOMMENDATIONS

1. Fall-out should be sampled systematically over greater areas, especially the areas downwind from ground zero. The size of this area might be larger than the area which is covered by the cloud before it begins to disintegrate appreciably.

2. Fall-out should be sampled for longer periods of time if test conditions are similar to those at this operation.

3. A larger number of duplicate stations should be set up in order to check further the random nature of fall-out.

4. Fall-out during the first hour after shot time should be sampled for shorter time intervals than those used during this operation.

5. Early decays should be run on some samples at the test site as soon as possible after the samples have been recovered so that activities corrected to a time soon after the detonation may be more reliable.

6. Liquid and solid fall-out should be sampled separately.

7. Radiochemical analyses should be performed on smaller size fractions as well as those fractions which were analyzed on this project.

8. A more thorough study should be made of the relation of gross fission decay with particle size.

9. Fall-out characteristics should continue to be evaluated from new and untested detonation conditions.

APPENDIX A

ROSTER OF PERSONNEL

The services of a large number of personnel were required to complete the analytical phase of this project. The authors wish to acknowledge the long and untiring efforts of many of these personnel, without which the project could not have been completed.

The analytical phase was divided into three main sections: activity measurements, total-particle-size analysis, and radiochemistry.

The personnel who were associated with activity measurements are:

Pvt William Andrews	Dora Meyers
Pfc Philip Bachman	Dean Miller
Pvt Peter Danco	Sgt Richard Miller
Cpl James Dejean	Pfc Charles Noble
Phyllis Gordon	Pfc Sherman Nornes
Pvt Raymond Grocella	Pfc David L. Rigotti
Pfc John Healy	Pfc Allen Roberts
Cpl Stephen Kahn	Pfc Robert Smith
Pfc Robert Kerr	Pfc Roger Stenerson
Pfc John Kinch	Mamye Talbott
Pfc Eugene Laskey	Pvt Walter Tallon
Pfc John Lynch	Pvt Donald Vetal
Pvt Mark Marshall	

The following personnel were concerned with the pretest planning, preparation, and laboratory analysis of intermittent-fall-out collector total fall-out:

Lt Dorothy E. Adams	Pfc Neal K. McNeill
Pfc Rudolph J. Bobka	Pfc Thomas J. Quigley
Pfc Carl S. Elder	Pfc Charles W. Reed
Pfc William J. Feingold	Pfc David L. Rigotti
Pvt Clinton D. Felton	Pfc Donald Stominger
Pvt John W. Klein II	W. Robert Van Antwerp
James E. Long	James D. Wilcox

The personnel who performed the radiochemical analyses of the gross-fall-out samples are:

Pfc Earl M. Belford	Cpl Robert A. Kulason
Pfc Frank Celio	Cpl Peter Merrett
Pfc Newell W. Emery	Pfc Paul D. Moore, Jr.
Sgt Willard G. Jannsen	Robert C. Tompkins
Lt Reilly C. Jensen	Pfc L. Robert Trotta
Philip W. Krey	

Field operations at Eniwetok (consisting in setting up, installing, and maintaining the sampling apparatus and installation and removal of samples) were carried out by Edwin H. Bouton, Project Officer, and the following personnel:

Pvt Lee Campbell	Pvt Thomas M. Oneson
Sgt Willard G. Jannsen	Maj John M. Roady, USAF
Lt Paul D. Jones, USAF	Michael J. Schumchyk
Pfc John S. Kemper	Pfc Thomas P. Weldon
Phillip W. Krey	Edward F. Wilsey
Pfc Paul D. Moore, Jr.	

APPENDIX B

COUNTING-CUP DATA, STATIONS J_n and J_s

Table B.1—INDIVIDUAL MIKE SHOT BETA ACTIVITY CORRECTED TO SAMPLING TIME
(Units of 10^3 dis/min)

Tray	Station and cup								
	J_n1	J_n2	J_n3	J_n4	J_s1	J_s2	J_s3	J_s4	J_{ns} av.
1	2090	2600	2720	2740	16700	13800	3510	18600	7840
2	6830	4730	427	2660	285	1160	2860	9150	3510
3	191	147	482	3260	445	75.1	228	751	739
4	68.0	277	182	Missing	362	428	422	418	308
5	66.3	154	564	879	280	155	103	237	307
6	190	102	164	511	372	465	27.5	225	257
7	136	47.8	130	191	93.7	83.8	335	26.5	130
8	16.4	41.2	42.2	67.7	231	192	181	233	125
9	12.8	156	18.8	43.4	89.6	11.6	82.2	28.6	55.3
10	25.6	113	14.0	85.2	65.2	80.9	11.9	95.0	61.3
11	20.7	40.7	Missing	37.8	11.7	6.21	32.9	77.7	32.6
12	22.5	48.3	75.8	266	44.9	33.0	7.09	2.51	62.5
13	19.1	38.9	44.4	128	20.5	27.8	23.2	59.8	45.2
14	20.0	51.5	59.4	67.3	29.4	52.7	19.3	19.7	39.9
15	32.2	48.3	54.3	97.0	8.95	19.5	21.4	15.9	37.2
16	67.3	30.5	8.44	3.53	7.75	18.6	7.09	93.5	29.6
17	14.8	14.1	42.8	5.53	6.85	1.79	1.93	5.95	11.7
18	3.10	2.87	14.6	3.12	1.78	Missing	7.06	1.31	4.83
19	3.08	15.5	2.29	5.03	1.94	3.88	11.0	8.45	8.39
20	Missing	2.03	25.9	13.0	7.56	4.15	24.2	2.40	11.3
21	0.987	3.64	5.38	Missing	1.55	12.6	16.6	17.5	8.32
22	3.79	2.24	9.39	20.3	14.0	4.73	14.3	19.9	11.1
23	6.22	9.15	1.36	13.6	4.77	7.24	31.9	26.2	12.5
24	6.36	7.95	6.11	7.16	2.04	Missing	9.88	13.9	7.63

APPENDIX C

INTERMITTENT-FALL-OUT COLLECTOR TOTAL-PARTICLE-ANALYSIS DATA

MIKE

DATA SHEET

	Sample	[illegible] (r)	[illegible] (r)	[illegible] (r)	[illegible] (r)	C_g		g/cm.²	g/cm.²	g/cm.²		g/cm.² (.1 - 1μ)	g/cm.² (1. - 10μ)	g/cm.² (10 - 100μ)	g/cm.² (100-[illegible])	
1																1
2	J_s - 1	0.25	0.59	128	200	4.5		1.20 x 10^{6}	2.20 x 10^{-7}	5.66 x 10^{-7}		4.24 x 10^{6}	1.24 x 10^{7}	1.31 x 10^{6}	1.62 x 10^{4}	2
3	J_s - 2															3
4	J_s - 3	0.32	0.57	98	124	4.1		3.49 x 10^{5}	7.91 x 10^{-7}	1.43 x 10^{-8}		5.08 x 10^{6}	4.34 x 10^{7}	3.49 x 10^{3}	4.32 x 10^{4}	4
5	J_s - 4	0.36	0.60	66	103	4.0		3.38 x 10^{5}	4.02 x 10^{-7}	3.11 x 10^{-7}		4.92 x 10^{6}	4.59 x 10^{6}	3.67 x 10^{3}	1.74 x 10^{4}	5
6	J_s - 5	0.23	0.43	92	302	4.7		3.70 x 10^{5}	5.24 x 10^{-7}	1.60 x 10^{-7}		8.43 x 10^{6}	2.67 x 10^{7}	1.99 x 10^{4}	3.64 x 10^{4}	6
7	J_s - 6	0.35	0.55	82	130	4.3		5.60 x 10^{5}	4.05 x 10^{-7}	6.64 x 10^{-8}		5.36 x 10^{6}	2.36 x 10^{7}	3.05 x 10^{3}	2.02 x 10^{4}	7
8	J_s - 7	0.25	0.46	28	127	4.3		7.39 x 10^{5}	3.39 x 10^{-7}	3.12 x 10^{-8}		7.20 x 10^{5}	1.85 x 10^{7}	8.03 x 10^{3}	6.40 x 10^{4}	8
9	J_s - 8	0.22	0.36	96	210	4.5		6.62 x 10^{6}	2.18 x 10^{-7}	6.54 x 10^{-9}		6.02 x 10^{5}	6.40 x 10^{7}	1.39 x 10^{3}	1.32 x 10^{4}	9
10	J_s - 9	0.24	0.40	67	119	4.2		2.09 x 10^{7}	4.30 x 10^{-7}	6.69 x 10^{-8}		1.67 x 10^{7}	2.37 x 10^{7}	4.16 x 10^{3}	1.52 x 10^{4}	10
11	J_s - 10	0.24	0.38	96	197	4.5		1.02 x 10^{7}	1.00 x 10^{-7}	4.49 x 10^{-8}		9.80 x 10^{6}	2.38 x 10^{7}	1.34 x 10^{3}	2.92 x 10^{4}	11
12	J_s - 11	0.20	0.46	144	225	4.6		5.49 x 10^{5}	4.02 x 10^{-7}	1.10 x 10^{-7}		5.18 x 10^{6}	3.06 x 10^{7}	1.23 x 10^{4}	2.13 x 10^{4}	12
13	J_s - 12															13
14	J_s - 13	0.23	0.43	60	98	4.2		4.97 x 10^{5}	2.34 x 10^{-7}	3.15 x 10^{-8}		4.78 x 10^{6}	3.86 x 10^{7}	3.39 x 10^{3}	3.80 x 10^{4}	14
15	J_s - 14	0.23	0.37	73	113	4.2		3.11 x 10^{5}	3.36 x 10^{-7}	3.34 x 10^{-8}		8.03 x 10^{6}	3.26 x 10^{6}	3.67 x 10^{3}	3.25 x 10^{4}	15
16	J_s - 15	0.20	0.38	130	276	4.7		3.10 x 10^{5}	2.96 x 10^{-7}	6.17 x 10^{-8}		8.93 x 10^{6}	1.72 x 10^{7}	1.30 x 10^{4}	8.25 x 10^{4}	16
17	J_s - 16	0.24	0.38	56	164	4.6		3.88 x 10^{5}	2.31 x 10^{-7}	3.87 x 10^{-8}		8.82 x 10^{6}	6.16 x 10^{6}	1.52 x 10^{3}	7.22 x 10^{4}	17
18	J_s - 17	0.24	0.39	48	128	4.5		5.75 x 10^{5}	2.54 x 10^{-7}	4.12 x 10^{-8}		6.43 x 10^{6}	1.16 x 10^{7}	1.21 x 10^{3}	1.60 x 10^{4}	18
19	J_s - 18	0.21	0.38	93	219	4.6		3.04 x 10^{5}	1.64 x 10^{-7}	8.47 x 10^{-8}		7.67 x 10^{6}	1.73 x 10^{7}	2.01 x 10^{3}	1.52 x 10^{4}	19
20	J_s - 19	0.29	0.50	93	140	4.2		4.44 x 10^{5}	2.88 x 10^{-7}	5.03 x 10^{-8}		4.26 x 10^{6}	1.78 x 10^{7}	1.78 x 10^{4}	1.38 x 10^{4}	20
21	J_s - 20	0.27	0.40	64	112	4.3		3.16 x 10^{5}	3.36 x 10^{-7}	4.34 x 10^{-8}		7.98 x 10^{6}	1.70 x 10^{7}	1.06 x 10^{4}	1.39 x 10^{4}	21
22	J_s - 21	0.27	0.49	72	173	4.3		3.26 x 10^{5}	3.42 x 10^{-7}	5.86 x 10^{-8}		5.85 x 10^{6}	4.04 x 10^{7}	2.22 x 10^{6}	1.30 x 10^{4}	22
23	J_s - 22															23
24	J_s - 23	0.23	0.45	148	330	4.7		3.82 x 10^{6}	7.63 x 10^{-7}	2.69 x 10^{-7}		5.67 x 10^{5}	1.51 x 10^{7}	3.10 x 10	4.35 x 10^{4}	24
25	J_s - 24	0.29	0.63	64	170	4.3		7.52 x 10^{5}	2.61 x 10^{-6}	3.18 x 10^{-7}		7.03 x 10^{6}	4.76 x 10^{7}	3.49 x 10	3.94 x 10^{4}	25
26																26
27																27
28	K - 1															28
29	K - 2															29
30	K - 3	0.21	0.52	83	720	5.1		5.08 x 10^{6}	4.15 x 10^{-7}	2.42 x 10^{-7}		4.68 x 10^{6}	3.86 x 10^{8}	3.62 x 10^{3}	1.24 x 10^{4}	30
31	K - 4	0.17	0.48	74	297	4.7		1.31 x 10^{7}	7.72 x 10^{-7}	2.17 x 10^{-7}		1.30 x 10^{7}	1.32 x 10^{6}	4.90 x 10^{3}	2.80 x 10^{4}	31
32	K - 5															32
33	K - 6	0.14	0.53	117	770	5.5		2.58 x 10^{6}	2.45 x 10^{-8}	8.21 x 10^{-7}		2.85 x 10^{6}	1.24 x 10^{7}	4.85 x 10^{3}	4.92 x 10^{4}	33
34	K - 7	0.31	0.52	82	96	3.9		3.32 x 10^{6}	8.26 x 10^{-7}	1.40 x 10^{-7}		7.27 x 10^{5}	1.04 x 10^{6}	4.28 x 10^{3}	3.98 x 10^{4}	34
35	K - 8	0.23	0.48	108	240	5.3		2.53 x 10^{6}	2.11 x 10^{-8}	7.37 x 10^{-7}		2.47 x 10^{6}	6.34 x 10^{6}	1.89 x 10^{3}	2.72 x 10^{4}	35
36	K - 9	0.14	0.32	75	86	4.4		2.93 x 10^{6}	4.15 x 10^{-7}	9.68 x 10^{-8}		1.90 x 10^{6}	2.10 x 10^{7}	1.85 x 10^{3}	1.16 x 10^{4}	36
37	K - 10	0.20	0.44	90	114	4.3		5.55 x 10^{6}	1.63 x 10^{-7}	2.04 x 10^{-7}		3.98 x 10^{6}	3.74 x 10^{7}	2.01 x 10^{3}	3.40 x 10^{4}	37
38	K - 11	0.14	0.48	80	98	5.8		9.68 x 10^{6}	1.03 x 10^{-8}	1.63 x 10^{-7}		8.92 x 10^{6}	6.78 x 10^{7}	5.50 x 10^{3}	3.76 x 10^{4}	38
39	K - 12															39
40	K - 13															40
41	K - 14	0.49	0.97	78	88	3.8		1.34 x 10^{6}	1.35 x 10^{-8}	2.09 x 10^{-7}		1.46 x 10^{7}	2.75 x 10^{8}	5.41 x 10^{7}	3.80 x 10^{4}	41
42	K - 15	0.38	0.68	118	138	4.1		2.67 x 10^{6}	2.08 x 10^{-7}	7.06 x 10^{-8}		3.28 x 10^{6}	3.67 x 10^{7}	3.03 x 10^{3}	1.52 x 10^{4}	42
43	K - 16	0.18	0.39	90	390	5.3		1.08 x 10^{6}	1.64 x 10^{-7}	6.22 x 10^{-8}		1.07 x 10^{6}	3.24 x 10^{6}	[illegible]	6.80 x 10^{4}	43
44	K - 17	0.17	0.33	80	113	4.4		3.38 x 10^{6}	2.96 x 10^{-7}	5.17 x 10^{-8}		3.35 x 10^{6}	1.21 x 10^{6}	3.03 x 10^{3}	1.32 x 10^{4}	44
45	K - 18	0.15	0.34	61	72	4.2		2.52 x 10^{6}	1.43 x 10^{-7}	1.62 x 10^{-7}		2.30 x 10^{6}	2.28 x 10^{6}	1.51 x 10^{3}	1.63 x 10^{4}	45
46	K - 19	0.15	0.33	102	149	4.6		2.70 x 10^{6}	4.02 x 10^{-7}	8.84 x 10^{-8}		2.68 x 10^{6}	1.48 x 10^{7}	2.24 x 10^{3}	2.54 x 10^{4}	46
47	K - 20	0.21	0.36	85	130	4.4		4.19 x 10^{6}	2.98 x 10^{-7}	5.54 x 10^{-8}		4.16 x 10^{6}	3.04 x 10^{7}	1.70 x 10^{3}	1.62 x 10^{4}	47
48	K - 21	0.11	0.30	80	135	5.1		1.39 x 10^{6}	2.43 x 10^{-7}	6.05 x 10^{-8}		1.37 x 10^{6}	1.96 x 10^{7}	2.19 x 10^{3}	2.80 x 10^{4}	48
49	K - 22															49
50	K - 23															50
51	K - 24															51
52																52

A Cml 0 b-10
(27 Mar 57)

Fig. C.1 —Mike shot, stations J_s and K.

MIKE

DATA SHEET

	Results	100 (r)	D max (r)	D 99 (r)	200 (r)	σ g	#/cm.²	#/cm.²	#/cm.²	#/cm.² (.1-1.0 μ)	#/cm.² (1. - 10 μ)	#/cm.² (10 - 100 μ)	#/cm.² (100 μ ...)
1													
2	M - 1												
3	M - 2	0.12	0.35	105	135	4.7	2.61×10^{6}	1.21×10^{-7}	7.17×10^{-8}	2.36×10^{6}	5.22×10^{4}	2.00×10^{3}	1.51×10^{2}
4	M - 3	0.17	0.37	125	445	5.0	2.27×10^{6}	2.83×10^{-7}	1.13×10^{-7}	2.26×10^{6}	5.02×10^{4}	1.71×10^{3}	1.24×10^{2}
5	M - 4	0.17	0.40	62	82	4.4	1.94×10^{6}	1.20×10^{-7}	4.62×10^{-8}	1.91×10^{6}	2.80×10^{4}	2.34×10^{3}	1.20×10^{2}
6	M - 5	0.21	0.34	70	85	4.4	6.99×10^{5}	1.10×10^{-7}	5.01×10^{-8}	6.91×10^{5}	9.30×10^{3}	2.84×10^{3}	9.20×10^{1}
7	M - 6	0.15	0.32	70	273	4.3	2.15×10^{6}	1.72×10^{-7}	4.20×10^{-8}	2.13×10^{6}	1.94×10^{4}	3.43×10^{3}	4.50×10^{1}
8	M - 7	0.17	0.37	74	98	4.2	2.72×10^{6}	1.56×10^{-7}	2.84×10^{-8}	2.71×10^{6}	3.42×10^{4}	1.85×10^{3}	4.30×10^{1}
9	M - 8	0.16	0.36	150	180	4.3	3.14×10^{6}	1.46×10^{-7}	3.47×10^{-7}	3.13×10^{6}	7.06×10^{4}	9.64×10^{2}	7.30×10^{1}
10	M - 9	0.16	0.29	90	173	4.6	2.52×10^{6}	2.63×10^{-7}	3.84×10^{-8}	2.51×10^{6}	7.34×10^{4}	1.41×10^{4}	9.40×10^{1}
11	M - 10	0.15	0.33	63	117	4.5	2.62×10^{6}	1.39×10^{-7}	2.07×10^{-7}	2.73×10^{6}	2.34×10^{4}	2.16×10^{4}	4.10×10^{2}
12	M - 11	0.15	0.35	110	180	4.8	1.49×10^{6}	4.44×10^{-7}	1.22×10^{-7}	1.45×10^{6}	3.53×10^{4}	1.54×10^{4}	2.74×10^{3}
13	M - 12	0.17	0.42	67	99	4.7	9.03×10^{5}	1.47×10^{-7}	1.98×10^{-7}	8.87×10^{5}	1.41×10^{4}	1.50×10^{3}	3.10×10^{1}
14	M - 13	0.15	0.37	78	250	4.7	2.29×10^{6}	2.63×10^{-7}	9.20×10^{-8}	2.27×10^{6}	1.70×10^{4}	1.71×10^{4}	1.02×10^{3}
15	M - 14	0.13	0.31	76	92	4.6	3.30×10^{6}	3.14×10^{-7}	5.00×10^{-8}	3.47×10^{6}	2.79×10^{4}	1.65×10^{4}	1.24×10^{3}
16	M - 15	0.15	0.46	59	95	4.3	7.23×10^{5}	3.36×10^{-7}	5.54×10^{-8}	7.10×10^{5}	1.13×10^{4}	2.00×10^{4}	1.63×10^{3}
17	M - 16	0.15	0.38	83	94	4.4	2.30×10^{6}	3.42×10^{-7}	5.34×10^{-8}	2.22×10^{6}	7.65×10^{4}	1.54×10^{4}	1.34×10^{3}
18	M - 17	0.13	0.28	88	132	4.7	1.98×10^{6}	2.25×10^{-7}	3.46×10^{-8}	1.97×10^{6}	5.56×10^{4}	1.30×10^{4}	1.17×10^{3}
19	M - 18	0.15	0.34	84	110	4.5	2.19×10^{6}	2.34×10^{-7}	4.25×10^{-8}	2.16×10^{6}	2.74×10^{4}	1.69×10^{4}	9.90×10^{2}
20	M - 19	0.13	0.29	73	88	4.4	2.61×10^{6}	1.86×10^{-7}	2.63×10^{-8}	2.59×10^{6}	2.13×10^{4}	1.57×10^{4}	5.40×10^{2}
21	M - 20	0.14	0.27	76	94	4.4	5.12×10^{6}	3.33×10^{-7}	5.29×10^{-8}	5.10×10^{6}	1.98×10^{4}	1.97×10^{3}	1.32×10^{3}
22	M - 21	0.12	0.33	56	102	4.5	2.14×10^{6}	1.37×10^{-7}	1.76×10^{-8}	2.11×10^{6}	3.01×10^{4}	2.19×10^{4}	3.90×10^{2}
23	M - 22	0.14	0.27	82	110	4.5	4.06×10^{6}	1.91×10^{-7}	1.46×10^{-8}	4.03×10^{6}	2.67×10^{4}	1.28×10^{4}	6.90×10^{2}
24	M - 23	0.15	0.37	56	120	4.7	2.36×10^{6}	2.56×10^{-7}	4.68×10^{-8}	2.28×10^{6}	5.33×10^{4}	1.68×10^{4}	1.40×10^{3}
25	M - 24	0.12	0.49	117	151	4.7	1.88×10^{6}	2.43×10^{-7}	3.11×10^{-8}	1.84×10^{6}	2.60×10^{4}	6.12×10^{3}	7.80×10^{2}
26													
27													
28	N - 1												
29	N - 2	0.17	0.54	243	200	4.7	2.62×10^{6}	1.54×10^{-6}	4.72×10^{-7}	2.53×10^{6}	8.45×10^{4}	7.70×10^{3}	1.07×10^{3}
30	N - 3	0.10	0.57	238	850	5.7	1.03×10^{6}	8.64×10^{-7}	5.10×10^{-7}	1.00×10^{6}	2.50×10^{4}	3.68×10^{3}	1.20×10^{3}
31	N - 4	0.17	0.66	[illegible]	450	5.1	8.90×10^{5}	5.90×10^{-7}	1.93×10^{-7}	8.41×10^{5}	4.60×10^{4}	2.78×10^{3}	1.72×10^{3}
32	N - 5	0.11	0.48	140	600	5.5	1.49×10^{6}	5.09×10^{-7}	2.42×10^{-7}	1.38×10^{6}	1.11×10^{5}	1.32×10^{4}	2.77×10^{3}
33	N - 6	0.19	0.66	164	520	4.8	6.14×10^{5}	3.92×10^{-7}	1.54×10^{-7}	5.55×10^{5}	5.67×10^{4}	2.11×10^{4}	1.87×10^{3}
34	N - 7	0.16	0.42	118	540	5.2	2.77×10^{6}	7.85×10^{-7}	1.32×10^{-7}	2.72×10^{6}	5.73×10^{4}	5.95×10^{3}	2.87×10^{3}
35	N - 8	0.16	0.42	86	104	4.4	1.73×10^{6}	4.33×10^{-7}	7.48×10^{-8}	1.65×10^{6}	1.52×10^{4}	2.34×10^{4}	1.70×10^{3}
36	N - 9	0.14	0.92	134	320	4.7	6.54×10^{6}	5.64×10^{-7}	1.33×10^{-7}	6.25×10^{6}	2.73×10^{5}	1.66×10^{4}	1.84×10^{3}
37	N - 10	0.17	0.76	137	156	4.6	5.75×10^{6}	2.33×10^{-7}	2.03×10^{-7}	5.40×10^{6}	3.64×10^{5}	2.47×10^{3}	4.96×10^{2}
38	N - 11	0.16	0.65	122	215	4.8	1.56×10^{6}	9.45×10^{-7}	3.12×10^{-7}	1.54×10^{6}	1.20×10^{5}	3.66×10^{3}	4.35×10^{2}
39	N - 12	0.15	0.60	58	290	4.9	1.42×10^{6}	1.15×10^{-6}	3.38×10^{-7}	1.40×10^{6}	1.86×10^{4}	5.90×10^{3}	4.54×10^{2}
40	N - 13	0.19	0.63	109	172	4.5	1.11×10^{6}	1.40×10^{-6}	1.11×10^{-7}	9.95×10^{5}	1.09×10^{5}	2.32×10^{3}	2.28×10^{2}
41	N - 14	0.13	0.44	143	180	4.7	7.20×10^{5}	3.27×10^{-7}	8.48×10^{-8}	7.18×10^{5}	9.90×10^{3}	1.18×10^{3}	2.35×10^{2}
42	N - 15	0.15	0.30	98	200	4.7	1.56×10^{6}	2.00×10^{-7}	5.75×10^{-8}	1.55×10^{6}	7.79×10^{3}	2.65×10^{3}	1.11×10^{2}
43	N - 16	0.20	0.43	72	84	4.3	1.41×10^{6}	2.13×10^{-7}	1.04×10^{-8}	1.43×10^{6}	5.84×10^{3}	1.21×10^{3}	4.66×10^{1}
44	N - 17	0.16	0.56	94	123	4.4	8.22×10^{5}	3.14×10^{-7}	5.86×10^{-8}	8.02×10^{5}	1.87×10^{4}	1.44×10^{3}	1.97×10^{2}
45	N - 18	0.21	0.46	50	90	4.3	8.46×10^{5}	1.22×10^{-7}	2.72×10^{-8}	8.18×10^{5}	2.56×10^{4}	1.01×10^{3}	6.20×10^{1}
46	N - 19	0.19	1.48	27	64	4.0	1.63×10^{6}	1.11×10^{-7}	8.32×10^{-8}	1.20×10^{6}	1.87×10^{5}	4.12×10^{4}	1.46×10^{2}
47	N - 20	0.15	0.28	105	265	4.9	2.98×10^{6}	1.62×10^{-7}	4.55×10^{-8}	2.96×10^{6}	2.24×10^{5}	1.05×10^{3}	8.15×10^{1}
48	N - 21	0.16	0.32	155	245	4.8	9.46×10^{5}	2.07×10^{-7}	6.75×10^{-8}	9.41×10^{5}	3.34×10^{3}	1.09×10^{3}	1.05×10^{2}
49	N - 22												
50	N - 23	0.15	0.34	88	120	4.5	1.55×10^{6}	3.23×10^{-7}	6.22×10^{-8}	1.53×10^{6}	1.52×10^{4}	1.85×10^{3}	1.78×10^{2}
51	N - 24	0.11	0.70	200	660	5.6	1.73×10^{6}	5.28×10^{-7}	3.30×10^{-7}	1.30×10^{6}	3.91×10^{4}	3.45×10^{3}	2.14×10^{2}
52													

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Fig. C.2—Mike shot, stations M and N.

MIKE — DATA SHEET

	Sample	[illegible] (μ)	D avg. (μ)	[illegible] (μ)	[illegible] (μ)	ρ_{g}		f/cm.²	β/cm.²	γ/cm.²		f/cm.² (.1 – 1μ)	f/cm.² (1 – 10μ)	f/cm.² (10 – 100μ)	f/cm.² (100 – ...μ)	
1																1
2	O – 1															2
3	O – 2	0.16	0.32	62	[illegible]	4.3		1.59×10^{6}	1.27×10^{-7}	1.61×10^{-7}		1.98×10^{6}	2.98×10^{5}	1.96×10^{4}	3.70×10^{3}	3
4	O – 3	0.15	0.32	110	170	4.6		1.27×10^{6}	1.84×10^{-7}	4.37×10^{-7}		1.27×10^{6}	1.09×10^{5}	1.21×10^{4}	1.14×10^{3}	4
5	O – 4	0.16	0.34	53	135	4.4		1.35×10^{6}	6.18×10^{-7}	5.96×10^{-7}		1.30×10^{6}	4.05×10^{5}	9.30×10^{4}	1.29×10^{3}	5
6	O – 5	0.16	0.39	76	98	4.5		1.46×10^{6}	2.80×10^{-7}	3.73×10^{-7}		1.42×10^{6}	3.96×10^{5}	4.11×10^{4}	1.21×10^{3}	6
7	O – 6	0.12	0.30	370	710	5.6		1.02×10^{6}	1.73×10^{-7}	1.92×10^{-7}		1.00×10^{6}	9.76×10^{5}	5.76×10^{4}	4.60×10^{3}	7
8	O – 7	0.11	0.33	64	173	4.8		1.10×10^{6}	3.99×10^{-7}	9.26×10^{-7}		1.06×10^{6}	3.10×10^{5}	5.52×10^{4}	1.78×10^{3}	8
9	O – 8	0.11	0.32	75	245	5.1		4.14×10^{6}	4.46×10^{-7}	1.01×10^{-7}		4.10×10^{6}	3.07×10^{5}	9.07×10^{4}	1.50×10^{3}	9
10	O – 9	0.14	0.30	105	165	4.6		1.18×10^{6}	1.78×10^{-7}	4.62×10^{-7}		1.18×10^{6}	1.56×10^{5}	7.53×10^{4}	1.08×10^{3}	10
11	O – 10	0.10	0.29	70	225	5.0		1.52×10^{6}	3.06×10^{-7}	6.38×10^{-7}		1.50×10^{6}	1.18×10^{5}	1.04×10^{4}	8.60×10^{3}	11
12	O – 11	0.10	0.37	68	81	4.5		2.49×10^{6}	1.29×10^{-7}	1.92×10^{-7}		2.40×10^{6}	1.41×10^{5}	9.96×10^{4}	6.00×10^{3}	12
13	O – 12	0.11	0.32	71	82	4.6		1.04×10^{6}	9.55×10^{-7}	1.31×10^{-7}		1.03×10^{6}	1.49×10^{5}	7.52×10^{4}	2.80×10^{3}	13
14	O – 13	0.11	0.30	73	82	4.4		1.60×10^{6}	1.49×10^{-7}	2.17×10^{-7}		1.59×10^{6}	1.38×10^{5}	1.01×10^{4}	1.30×10^{3}	14
15	O – 14	0.11	0.44	95	172	4.8		2.38×10^{6}	1.01×10^{-7}	9.57×10^{-7}		2.27×10^{6}	1.02×10^{5}	5.14×10^{4}	1.51×10^{3}	15
16	O – 15	0.16	0.45	92	138	4.4		1.12×10^{6}	2.46×10^{-7}	4.81×10^{-7}		1.09×10^{6}	2.52×10^{5}	1.42×10^{4}	1.30×10^{3}	16
17	O – 16	0.15	0.32	97	158	4.8		3.45×10^{6}	2.21×10^{-7}	5.19×10^{-7}		3.43×10^{6}	1.17×10^{5}	7.76×10^{4}	1.28×10^{3}	17
18	O – 17	0.18	0.35	74	117	4.4		1.60×10^{6}	1.71×10^{-7}	2.92×10^{-7}		1.59×10^{6}	1.36×10^{5}	1.46×10^{4}	6.51×10^{3}	18
19	O – 18	0.16	0.35	103	138	4.4		1.44×10^{6}	2.12×10^{-7}	4.47×10^{-7}		1.44×10^{6}	6.85×10^{5}	1.02×10^{4}	1.40×10^{3}	19
20	O – 19	0.15	0.28	120	180	4.7		3.51×10^{6}	2.29×10^{-7}	5.75×10^{-7}		3.50×10^{6}	4.41×10^{5}	8.27×10^{4}	1.29×10^{3}	20
21	O – 20	0.11	0.30	134	180	4.9		2.38×10^{6}	2.74×10^{-7}	7.06×10^{-7}		2.37×10^{6}	6.19×10^{5}	8.91×10^{4}	1.67×10^{3}	21
22	O – 21	0.17	0.33	110	130	4.4		8.13×10^{6}	1.41×10^{-7}	2.91×10^{-7}		8.10×10^{6}	2.54×10^{5}	6.21×10^{4}	1.14×10^{3}	22
23	O – 22	0.11	0.25	117	170	4.8		4.25×10^{6}	1.95×10^{-7}	4.58×10^{-7}		4.24×10^{6}	5.67×10^{5}	9.38×10^{4}	1.14×10^{3}	23
24	O – 23	0.11	0.28	115	148	4.7		1.91×10^{6}	2.32×10^{-7}	5.10×10^{-7}		1.98×10^{6}	4.84×10^{5}	1.10×10^{4}	1.64×10^{3}	24
25	O – 24	0.15	0.27	90	125	4.5		5.14×10^{6}	2.10×10^{-7}	3.08×10^{-7}		5.11×10^{6}	2.05×10^{5}	1.36×10^{4}	1.14×10^{3}	25
26																26
27																27
28	R_g – 1	0.22	0.36	28	140	4.4		7.53×10^{6}	8.65×10^{-7}	8.63×10^{-7}		7.03×10^{6}	4.76×10^{5}	2.75×10^{4}	1.10×10^{3}	28
29	R_g – 2	0.17	0.43	54	130	4.5		2.19×10^{6}	1.38×10^{-7}	1.04×10^{-7}		2.08×10^{6}	1.06×10^{5}	1.90×10^{4}	3.60×10^{3}	29
30	R_g – 3	0.10	0.23	36	94	4.6		1.68×10^{6}	2.17×10^{-7}	2.97×10^{-7}		1.67×10^{6}	9.06×10^{5}	1.89×10^{4}	1.60×10^{3}	30
31	R_g – 4	0.10	0.37	150	720	5.6		3.11×10^{6}	4.65×10^{-7}	3.02×10^{-7}		3.03×10^{6}	6.95×10^{5}	4.70×10^{4}	4.30×10^{3}	31
32	R_g – 5	0.15	0.56	95	350	5.0		1.73×10^{6}	4.55×10^{-7}	1.78×10^{-7}		1.59×10^{6}	1.35×10^{5}	4.37×10^{4}	8.04×10^{3}	32
33	R_g – 6	0.19	0.36	80	660	5.2		6.98×10^{6}	2.94×10^{-7}	1.43×10^{-7}		6.82×10^{6}	1.58×10^{5}	2.21×10^{4}	2.20×10^{3}	33
34	R_g – 7	0.19	0.37	69	820	5.4		4.16×10^{6}	2.92×10^{-7}	8.63×10^{-7}		4.09×10^{6}	6.71×10^{5}	2.63×10^{4}	5.60×10^{3}	34
35	R_g – 8	0.19	0.35	68	97	4.3		6.94×10^{6}	2.87×10^{-7}	3.90×10^{-7}		6.84×10^{6}	6.66×10^{5}	3.91×10^{4}	8.80×10^{3}	35
36	R_g – 9	0.16	0.35	78	95	4.3		3.03×10^{6}	1.99×10^{-7}	2.84×10^{-7}		2.96×10^{6}	7.28×10^{5}	2.12×10^{4}	7.28×10^{3}	36
37	R_g – 10	0.14	0.35	66	88	4.3		2.23×10^{6}	2.04×10^{-7}	2.73×10^{-7}		2.21×10^{6}	2.16×10^{5}	2.39×10^{4}	5.80×10^{3}	37
38	R_g – 11	0.17	0.42	82	190	4.7		1.56×10^{6}	2.61×10^{-7}	5.86×10^{-7}		1.50×10^{6}	5.61×10^{5}	2.08×10^{4}	1.04×10^{3}	38
39	R_g – 12	0.16	0.41	100	640	5.1		3.51×10^{6}	6.35×10^{-7}	2.25×10^{-7}		3.42×10^{6}	9.36×10^{5}	1.94×10^{4}	2.02×10^{3}	39
40	R_g – 13	0.18	0.64	110	160	4.5		7.24×10^{6}	3.92×10^{-7}	8.37×10^{-7}		6.79×10^{6}	4.34×10^{5}	2.09×10^{4}	1.90×10^{3}	40
41	R_g – 14	0.18	0.37	93	160	4.5		2.79×10^{6}	2.88×10^{-7}	6.33×10^{-7}		2.74×10^{6}	4.97×10^{5}	2.14×10^{4}	1.33×10^{3}	41
42	R_g – 15	0.15	0.37	73	95	4.4		1.39×10^{6}	3.48×10^{-7}	1.88×10^{-7}		1.36×10^{6}	2.61×10^{5}	2.12×10^{4}	8.80×10^{3}	42
43	R_g – 16	0.17	0.31	66	77	4.2		3.36×10^{6}	2.03×10^{-7}	2.65×10^{-7}		3.32×10^{6}	2.93×10^{5}	1.97×10^{4}	1.30×10^{3}	43
44	R_g – 17	0.16	0.33	60	66	4.1		2.44×10^{6}	1.80×10^{-7}	1.96×10^{-7}		2.42×10^{6}	2.23×10^{5}	2.37×10^{4}	1.20×10^{3}	44
45	R_g – 18	0.17	0.33	36	74	4.2		2.37×10^{6}	1.72×10^{-7}	1.95×10^{-7}		2.34×10^{6}	1.66×10^{5}	2.14×10^{4}	2.70×10^{3}	45
46	R_g – 19	0.18	0.34	46	68	4.1		1.76×10^{6}	1.27×10^{-7}	1.21×10^{-7}		1.75×10^{6}	2.59×10^{5}	1.59×10^{4}	1.40×10^{3}	46
47	R_g – 20	0.17	0.38	86	220	4.7		1.01×10^{6}	2.83×10^{-7}	2.97×10^{-7}		9.87×10^{5}	2.54×10^{5}	1.69×10^{4}	1.00×10^{3}	47
48	R_g – 21	0.10	0.28	78	100	4.8		2.75×10^{6}	2.35×10^{-7}	3.65×10^{-7}		2.74×10^{6}	1.27×10^{5}	1.84×10^{4}	8.90×10^{3}	48
49	R_g – 22	0.17	0.38	65	410	5.0		9.85×10^{6}	1.83×10^{-7}	3.06×10^{-7}		9.70×10^{6}	1.34×10^{5}	1.68×10^{4}	2.40×10^{3}	49
50	R_g – 23	0.15	0.31	92	120	4.5		3.31×10^{6}	3.30×10^{-7}	6.07×10^{-7}		3.09×10^{6}	2.01×10^{5}	1.92×10^{4}	1.84×10^{3}	50
51																51
52																52

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Fig. C.3—Mike shot, stations O and R_g.

MIKE

DATA SHEET

Sample	γ30 (r)	100 (r)	e/cm²	γ/cm²	β/cm² (3 – 10%)	β/cm² (10 – 100%)	β/cm² (100 ...)
S - 1	96	470	2.28 x 10[illegible]	8.52 x 10[illegible]	1.02 x 10[illegible]	1.81 x 10[illegible]	8.80 x 10[illegible]
S - 2	78	75	1.14 x 10[illegible]	3.42 x 10[illegible]	2.48 x 10[illegible]	1.66 x 10[illegible]	1.50 x 10[illegible]
S - 3	66	77	2.92 x 10[illegible]	5.49 x 10[illegible]	1.50 x 10[illegible]	2.42 x 10[illegible]	6.80 x 10[illegible]
S - 4	66	450	1.18 x 10[illegible]	3.26 x 10[illegible]	1.55 x 10[illegible]	2.90 x 10[illegible]	1.78 x 10[illegible]
S - 5	110	168	2.92 x 10[illegible]	7.90 x 10[illegible]	5.88 x 10[illegible]	1.33 x 10[illegible]	1.26 x 10[illegible]
S - 6	200	610	2.32 x 10[illegible]	1.29 x 10[illegible]	5.00 x 10[illegible]	1.23 x 10[illegible]	2.60 x 10[illegible]
S - 7	80	460	1.74 x 10[illegible]	7.22 x 10[illegible]	1.08 x 10[illegible]	2.04 x 10[illegible]	1.90 x 10[illegible]
S - 8	74	400	1.04 x 10[illegible]	1.97 x 10[illegible]	1.40 x 10[illegible]	1.23 x 10[illegible]	1.00 x 10[illegible]
S - 9	99	75	1.60 x 10[illegible]	1.81 x 10[illegible]	1.62 x 10[illegible]	4.61 x 10[illegible]	3.00 x 10[illegible]
S - 10	76	166	9.54 x 10[illegible]	1.73 x 10[illegible]	1.92 x 10[illegible]	1.27 x 10[illegible]	3.70 x 10[illegible]
S - 11	93	100	1.85 x 10[illegible]	2.13 x 10[illegible]	4.33 x 10[illegible]	2.93 x 10[illegible]	4.10 x 10[illegible]
S - 12	72	72	1.46 x 10[illegible]	8.00 x 10[illegible]	7.28 x 10[illegible]	5.61 x 10[illegible]	3.20 x 10[illegible]
S - 13	69	92	2.12 x 10[illegible]	3.44 x 10[illegible]	2.04 x 10[illegible]	3.63 x 10[illegible]	5.60 x 10[illegible]
S - 14	44	145	2.27 x 10[illegible]	3.56 x 10[illegible]	5.38 x 10[illegible]	4.74 x 10[illegible]	4.10 x 10[illegible]
S - 15	54	68	1.60 x 10[illegible]	1.28 x 10[illegible]	4.73 x 10[illegible]	4.27 x 10[illegible]	1.50 x 10[illegible]
S - 16	54	125	6.47 x 10[illegible]	7.22 x 10[illegible]	2.97 x 10[illegible]	1.26 x 10[illegible]	1.60 x 10[illegible]
S - 17	95	72	1.22 x 10[illegible]	1.39 x 10[illegible]	2.62 x 10[illegible]	2.24 x 10[illegible]	1.50 x 10[illegible]
S - 18	19	80	9.26 x 10[illegible]	7.43 x 10[illegible]	2.76 x 10[illegible]	3.12 x 10[illegible]	1.28 x 10[illegible]
S - 19	71	76	4.05 x 10[illegible]	3.87 x 10[illegible]	1.32 x 10[illegible]	7.54 x 10[illegible]	3.40 x 10[illegible]
S - 20	48	79	6.44 x 10[illegible]	1.05 x 10[illegible]	4.84 x 10[illegible]	4.20 x 10[illegible]	3.50 x 10[illegible]
S - 21	84	105	1.20 x 10[illegible]	2.13 x 10[illegible]	7.01 x 10[illegible]	6.70 x 10[illegible]	5.31 x 10[illegible]
S - 22	67	88	7.94 x 10[illegible]	1.01 x 10[illegible]	1.60 x 10[illegible]	9.91 x 10[illegible]	2.64 x 10[illegible]
S - 23	76	90	1.61 x 10[illegible]	2.33 x 10[illegible]	1.03 x 10[illegible]	1.84 x 10[illegible]	6.42 x 10[illegible]
S - 24	89	300	1.79 x 10[illegible]	4.84 x 10[illegible]	1.06 x 10[illegible]	1.09 x 10[illegible]	6.38 x 10[illegible]
U - 1	92	120	1.72 x 10[illegible]	1.49 x 10[illegible]	2.63 x 10[illegible]	7.29 x 10[illegible]	1.03 x 10[illegible]
U - 2	110	137	2.91 x 10[illegible]	1.66 x 10[illegible]	1.27 x 10[illegible]	1.97 x 10[illegible]	1.48 x 10[illegible]
U - 3	72	99	1.45 x 10[illegible]	2.11 x 10[illegible]	1.11 x 10[illegible]	1.50 x 10[illegible]	5.20 x 10[illegible]
U - 4	70	110	1.98 x 10[illegible]	2.28 x 10[illegible]	1.71 x 10[illegible]	9.73 x 10[illegible]	3.45 x 10[illegible]
U - 5	86	105	2.00 x 10[illegible]	3.49 x 10[illegible]	6.70 x 10[illegible]	1.20 x 10[illegible]	1.12 x 10[illegible]
U - 6	90	106	1.33 x 10[illegible]	2.15 x 10[illegible]	1.12 x 10[illegible]	1.10 x 10[illegible]	6.53 x 10[illegible]
U - 7	96	107	1.47 x 10[illegible]	2.46 x 10[illegible]	5.35 x 10[illegible]	8.52 x 10[illegible]	8.24 x 10[illegible]
U - 8	81	119	1.26 x 10[illegible]	2.17 x 10[illegible]	8.52 x 10[illegible]	1.28 x 10[illegible]	6.26 x 10[illegible]
U - 9	79	109	1.36 x 10[illegible]	2.20 x 10[illegible]	7.69 x 10[illegible]	1.05 x 10[illegible]	5.72 x 10[illegible]
U - 10	100	144	1.11 x 10[illegible]	2.35 x 10[illegible]	2.51 x 10[illegible]	5.86 x 10[illegible]	6.30 x 10[illegible]
U - 11	100	130	2.58 x 10[illegible]	5.54 x 10[illegible]	9.09 x 10[illegible]	2.75 x 10[illegible]	1.40 x 10[illegible]
U - 12	77	138	1.87 x 10[illegible]	3.83 x 10[illegible]	1.54 x 10[illegible]	1.30 x 10[illegible]	6.63 x 10[illegible]
U - 13	64	90	1.53 x 10[illegible]	2.13 x 10[illegible]	8.54 x 10[illegible]	1.94 x 10[illegible]	4.93 x 10[illegible]
U - 14	78	124	1.95 x 10[illegible]	2.15 x 10[illegible]	7.89 x 10[illegible]	1.52 x 10[illegible]	6.80 x 10[illegible]
U - 15	79	97	1.00 x 10[illegible]	1.66 x 10[illegible]	2.48 x 10[illegible]	6.91 x 10[illegible]	5.20 x 10[illegible]
U - 16	74	111	9.87 x 10[illegible]	1.54 x 10[illegible]	7.08 x 10[illegible]	1.04 x 10[illegible]	4.00 x 10[illegible]
U - 17	119	148	1.47 x 10[illegible]	3.37 x 10[illegible]	2.92 x 10[illegible]	5.28 x 10[illegible]	1.08 x 10[illegible]
U - 18	86	190	1.03 x 10[illegible]	2.06 x 10[illegible]	4.55 x 10[illegible]	3.34 x 10[illegible]	4.46 x 10[illegible]
U - 19	115	142	1.35 x 10[illegible]	2.87 x 10[illegible]	1.93 x 10[illegible]	8.10 x 10[illegible]	9.70 x 10[illegible]
U - 20	73	96	1.11 x 10[illegible]	1.83 x 10[illegible]	1.40 x 10[illegible]	7.90 x 10[illegible]	1.86 x 10[illegible]
U - 21	102	140	1.13 x 10[illegible]	2.23 x 10[illegible]	8.36 x 10[illegible]	7.94 x 10[illegible]	7.28 x 10[illegible]
U - 22	84	110	1.90 x 10[illegible]	1.30 x 10[illegible]	7.38 x 10[illegible]	1.72 x 10[illegible]	9.40 x 10[illegible]
U - 23	103	130	4.93 x 10[illegible]	1.06 x 10[illegible]	1.00 x 10[illegible]	2.27 x 10[illegible]	3.32 x 10[illegible]
U - 24	79	94	5.28 x 10[illegible]	5.33 x 10[illegible]	8.96 x 10[illegible]	2.24 x 10[illegible]	1.46 x 10[illegible]

A Cml C 1-10
(27 Mar 47)

Fig. C.4—Mike shot, stations S and U.

MIKE

DATA SHEET

	Sample	IR (r)	R em. (r)	Σ IR (r)	IB (r)	E_γ		γ/cm²	α/cm²	β/cm²		γ/cm² (1.3 - 3 k)	γ/cm² (0.8 - 30 k)	γ/cm² (30 - 100 k)	γ/cm² (100 - ...)	
1																1
2	LL-1	0.12	0.24	59	112	4.5		8.21 x 10^5	2.75 x 10^-1	1.21 x 10^-1		8.20 x 10^5	8.86 x 10^5	1.12 x 10^4	1.66 x 10^7	2
3	LL-2	0.16	0.40	27	79	4.2		9.12 x 10^5	5.12 x 10^-1	5.08 x 10^-1		8.88 x 10^5	2.28 x 10^5	7.34 x 10^4	1.70 x 10^7	3
4	LL-3	0.11	0.25	372	460	5.3		1.32 x 10^5	1.84 x 10^-1	1.21 x 10^-1		1.31 x 10^5	1.33 x 10^5	3.34 x 10^4	4.78 x 10^7	4
5	LL-4	0.11	0.25	65	112	4.6		1.61 x 10^5	4.11 x 10^-1	4.33 x 10^-1		1.96 x 10^5	4.57 x 10^5	4.02 x 10^4	9.10 x 10^6	5
6	LL-5	0.16	0.32	35	70	4.2		2.07 x 10^5	7.50 x 10^-1	6.63 x 10^-1		2.05 x 10^5	2.13 x 10^5	2.02 x 10^4	1.20 x 10^7	6
7	LL-6	0.13	0.27	45	86	4.4		2.67 x 10^5	5.10 x 10^-1	5.06 x 10^-1		2.62 x 10^5	4.92 x 10^5	4.21 x 10^4	1.20 x 10^7	7
8	LL-7	0.11	0.28	21	70	4.3		1.35 x 10^5	1.07 x 10^-1	6.21 x 10^-1		1.30 x 10^5	6.22 x 10^5	1.98 x 10^4	8.60 x 10^6	8
9	LL-8	0.13	0.26	69	99	4.4		4.30 x 10^5	6.87 x 10^-1	8.44 x 10^-1		4.26 x 10^5	4.08 x 10^5	4.36 x 10^4	2.14 x 10^7	9
10	LL-9	0.13	0.25	98	142	4.6		3.92 x 10^5	6.80 x 10^-1	1.26 x 10^-1		3.81 x 10^5	9.04 x 10^5	4.98 x 10^4	4.40 x 10^7	10
11	LL-10	0.12	0.23	106	160	4.5		5.12 x 10^5	5.97 x 10^-1	1.33 x 10^-1		5.11 x 10^5	1.36 x 10^5	4.30 x 10^4	3.02 x 10^7	11
12	LL-11	0.11	0.22	74	135	4.7		1.12 x 10^6	8.60 x 10^-1	1.34 x 10^-1		1.05 x 10^6	7.44 x 10^5	7.40 x 10^4	4.40 x 10^7	12
13	LL-12	0.11	0.33	204	195	4.7		2.07 x 10^6	1.48 x 10^-1	3.06 x 10^-1		2.03 x 10^6	3.60 x 10^5	9.88 x 10^4	8.60 x 10^7	13
14	LL-13	0.12	0.31	74	110	4.5		1.42 x 10^6	1.33 x 10^-1	2.08 x 10^-1		1.40 x 10^6	1.30 x 10^5	1.73 x 10^4	6.40 x 10^7	14
15	LL-14	0.13	0.27	44	184	4.8		4.34 x 10^6	8.48 x 10^-1	1.24 x 10^-1		4.29 x 10^6	4.68 x 10^5	1.02 x 10^4	2.00 x 10^7	15
16	LL-15	0.16	0.34	72	87	4.3		1.29 x 10^6	8.00 x 10^-1	8.50 x 10^-1		1.24 x 10^6	4.40 x 10^5	7.78 x 10^4	2.16 x 10^7	16
17	LL-16	0.13	0.29	36	73	4.3		1.15 x 10^6	4.49 x 10^-1	4.84 x 10^-1		1.34 x 10^6	1.19 x 10^5	5.49 x 10^4	8.20 x 10^6	17
18	LL-17	0.17	0.29	98	166	4.5		1.99 x 10^6	6.80 x 10^-1	1.46 x 10^-1		1.96 x 10^6	5.24 x 10^5	3.32 x 10^4	3.55 x 10^7	18
19	LL-19	0.13	0.28	56	87	4.4		2.72 x 10^6	6.93 x 10^-1	7.94 x 10^-1		2.68 x 10^6	5.55 x 10^5	5.88 x 10^4	2.13 x 10^7	19
20	LL-22	0.12	0.27	55	66	4.3		2.26 x 10^6	8.31 x 10^-1	9.34 x 10^-1		2.26 x 10^6	2.58 x 10^5	9.77 x 10^4	3.33 x 10^6	20

A Cal C 4-10
(27 Mar 47)

Fig. C.5—Mike shot, Station LL_{II}.

KING — DATA SHEET

Sample	β 1M (r)	1M (r)	g/cm²	γ/cm²	β/cm² (2 – 10 μ)	β/cm² (10 – 100 μ)	β/cm² (100 μ–)
J - 1	59	67	2.35×10^{-7}	3.41×10^{-8}	2.17×10^{4}	3.46×10^{3}	4.36×10^{3}
J - 2	72	110	5.69×10^{-7}	9.36×10^{-8}	3.39×10^{4}	3.48×10^{3}	2.10×10^{4}
J - 3	61	272	4.40×10^{-7}	1.19×10^{-7}	2.50×10^{4}	4.21×10^{3}	1.42×10^{4}
J - 4	207	330	9.30×10^{-7}	3.85×10^{-7}	7.04×10^{4}	2.33×10^{3}	5.36×10^{4}
J - 5	98	216	5.80×10^{-7}	1.72×10^{-7}	2.99×10^{4}	4.11×10^{3}	2.42×10^{4}
J - 6	123	283	5.45×10^{-7}	1.67×10^{-7}	8.67×10^{4}	3.89×10^{3}	2.00×10^{4}
J - 7	60	382	7.01×10^{-7}	1.67×10^{-7}	1.10×10^{4}	1.61×10^{4}	1.58×10^{4}
J - 8	160	278	7.79×10^{-7}	2.52×10^{-7}	6.06×10^{4}	8.13×10^{3}	3.60×10^{4}
J - 9	77	317	5.69×10^{-7}	1.02×10^{-7}	1.82×10^{4}	4.95×10^{3}	2.70×10^{4}
J - 10	93	120	7.35×10^{-7}	1.40×10^{-7}	1.92×10^{4}	4.91×10^{3}	4.30×10^{3}
J - 11	80	112	4.95×10^{-7}	1.00×10^{-7}	2.30×10^{4}	3.02×10^{3}	1.96×10^{4}
J - 12	100	130	3.08×10^{-7}	6.06×10^{-8}	1.91×10^{4}	1.82×10^{3}	2.13×10^{4}
J - 13	80	138	2.65×10^{-7}	6.06×10^{-8}	1.31×10^{4}	2.22×10^{3}	1.18×10^{4}
J - 14	98	400	2.47×10^{-7}	8.46×10^{-8}	2.78×10^{4}	1.80×10^{4}	8.31×10^{3}
J - 15	92	208	3.90×10^{-7}	4.88×10^{-8}	6.47×10^{4}	1.05×10^{3}	7.98×10^{3}
J - 16	124	138	3.28×10^{-7}	8.55×10^{-8}	2.30×10^{4}	2.19×10^{3}	2.16×10^{4}
J - 17	95	147	2.48×10^{-7}	6.93×10^{-8}	4.41×10^{4}	1.75×10^{3}	1.92×10^{4}
J - 18	98	152	2.93×10^{-7}	5.78×10^{-8}	2.34×10^{4}	2.00×10^{3}	1.66×10^{4}
J - 19	108	142	3.95×10^{-7}	8.79×10^{-8}	1.65×10^{4}	2.25×10^{3}	2.54×10^{4}
J - 20	135	178	4.49×10^{-7}	1.31×10^{-7}	3.80×10^{4}	2.56×10^{3}	2.88×10^{4}
J - 21	78	91	3.82×10^{-7}	5.82×10^{-8}	3.15×10^{4}	3.98×10^{3}	1.77×10^{4}
J - 22	70	133	2.27×10^{-7}	4.49×10^{-8}	3.31×10^{4}	5.47×10^{3}	8.64×10^{3}
J - 23	104	187	2.51×10^{-7}	6.66×10^{-8}	1.08×10^{4}	1.46×10^{3}	1.12×10^{3}
J - 24	123	380	1.72×10^{-7}	4.30×10^{-8}	1.41×10^{4}	5.12×10^{3}	4.30×10^{3}
L - 1	60	67	2.88×10^{-7}	3.43×10^{-8}	3.15×10^{4}	4.49×10^{3}	1.80×10^{3}
L - 2	48	61	1.27×10^{-7}	2.84×10^{-8}	3.72×10^{4}	4.75×10^{3}	1.40×10^{3}
L - 3	74	130	3.21×10^{-7}	6.19×10^{-8}	9.73×10^{3}	2.13×10^{3}	1.22×10^{4}
L - 4	76	115	4.73×10^{-7}	7.96×10^{-8}	1.54×10^{4}	4.20×10^{3}	1.90×10^{4}
L - 5	67	118	2.40×10^{-7}	3.90×10^{-8}	1.76×10^{4}	3.63×10^{3}	8.52×10^{3}
L - 6	54	73	3.82×10^{-7}	4.17×10^{-8}	4.51×10^{4}	6.53×10^{3}	8.00×10^{3}
L - 7	83	170	2.01×10^{-7}	4.65×10^{-8}	1.44×10^{4}	1.48×10^{3}	8.25×10^{3}
L - 8	60	75	3.27×10^{-7}	4.39×10^{-8}	2.23×10^{4}	1.88×10^{3}	7.60×10^{3}
L - 9	75	130	3.39×10^{-7}	3.53×10^{-8}	3.43×10^{4}	2.13×10^{3}	1.42×10^{4}
L - 10	73	112	3.56×10^{-7}	6.34×10^{-8}	1.86×10^{4}	2.62×10^{3}	1.54×10^{4}
L - 11	145	295	3.95×10^{-7}	1.44×10^{-7}	3.76×10^{3}	1.52×10^{3}	2.12×10^{4}
L - 12	136	173	4.44×10^{-7}	1.19×10^{-7}	1.04×10^{4}	2.12×10^{3}	2.96×10^{4}
L - 13	70	80	3.30×10^{-7}	5.00×10^{-8}	7.16×10^{3}	2.06×10^{3}	1.28×10^{4}
L - 14	143	200	3.60×10^{-7}	1.00×10^{-7}	3.90×10^{3}	1.55×10^{3}	2.40×10^{4}
L - 15	93	162	4.71×10^{-7}	9.98×10^{-8}	2.13×10^{4}	4.06×10^{3}	2.46×10^{4}
L - 16	82	230	3.53×10^{-7}	9.25×10^{-8}	2.11×10^{4}	3.79×10^{3}	1.06×10^{4}
L - 17	64	73	2.50×10^{-7}	3.49×10^{-8}	1.36×10^{4}	1.94×10^{3}	7.20×10^{3}
L - 18	71	84	3.46×10^{-7}	5.08×10^{-8}	2.17×10^{4}	2.98×10^{3}	1.28×10^{4}
L - 19	66	81	2.70×10^{-7}	4.02×10^{-8}	1.33×10^{4}	2.19×10^{3}	9.20×10^{3}
L - 20	92	168	2.06×10^{-7}	4.99×10^{-8}	8.90×10^{3}	2.70×10^{3}	9.90×10^{3}
L - 21	55	90	3.18×10^{-7}	5.94×10^{-8}	6.52×10^{3}	1.60×10^{3}	1.55×10^{3}
L - 22	104	130	2.61×10^{-7}	5.29×10^{-8}	1.30×10^{4}	2.06×10^{3}	1.56×10^{4}
L - 23	135	198	8.27×10^{-7}	2.35×10^{-8}	6.02×10^{3}	2.56×10^{3}	4.92×10^{3}
L - 24	90	76	3.15×10^{-7}	4.34×10^{-8}	2.79×10^{4}	5.24×10^{3}	6.20×10^{3}

A Cml C 4-10
(27 Mar 47)

Fig. C.6—King shot, stations J_n and L

KING

DATA SHEET

	Sample	RBD (r)	β ope. (r)	f 30 (r)	RBD (r)	σ_g		β/cm²	γ/cm²	n/cm²		f/cm² (.1 – 1e)	f/cm² (1 – 10e)	f/cm² (10 – 100e)	f/cm² (100 – e)	
1																1
2	N - 1	0.12	0.54	82	102	4.4		5.91×10^{6}	3.48×10^{-7}	5.92×10^{-7}		5.78×10^{6}	9.50×10^{5}	2.70×10^{3}	1.66×10^{2}	2
3	N - 5	0.13	0.62	68	77	4.2		8.04×10^{6}	4.97×10^{-7}	7.82×10^{-7}		7.69×10^{6}	3.05×10^{5}	4.66×10^{3}	1.04×10^{2}	3
4	N - 19	0.13	0.33	94	135	4.5		1.35×10^{6}	2.45×10^{-7}	1.98×10^{-7}		1.34×10^{6}	8.50×10^{5}	1.90×10^{3}	1.14×10^{2}	4
5	N - 20	0.15	0.53	90	118	4.4		6.36×10^{6}	1.02×10^{-7}	5.47×10^{-7}		6.20×10^{6}	1.35×10^{5}	2.75×10^{3}	1.58×10^{2}	5
6	N - 21			77	119				2.90×10^{-7}	4.69×10^{-7}			1.57×10^{5}	4.94×10^{3}	1.22×10^{2}	6
7	N - 22	0.12	0.32	112	130	4.6		2.97×10^{6}	3.48×10^{-7}	7.11×10^{-7}		2.53×10^{6}	3.55×10^{5}	1.56×10^{3}	1.01×10^{2}	7
8	N - 23	0.13	0.66	83	108	4.5		4.38×10^{6}	2.46×10^{-7}	4.13×10^{-7}		4.35×10^{6}	2.12×10^{5}	2.12×10^{3}	1.20×10^{2}	8
9	N - 24	0.16	0.52	94	125	4.4		9.82×10^{6}	4.89×10^{-7}	1.05×10^{-7}		8.43×10^{6}	3.68×10^{5}	1.78×10^{3}	2.74×10^{2}	9
10																10
11																11
12	O - 1	0.15	0.48	24	150	4.3		9.98×10^{6}	1.03×10^{-7}	1.15×10^{-7}		9.56×10^{6}	1.84×10^{5}	2.86×10^{3}	2.30×10^{1}	12
13	O - 2	0.17	0.45	45	64	4.1		1.55×10^{6}	2.20×10^{-7}	5.53×10^{-7}		1.49×10^{6}	5.49×10^{5}	1.96×10^{3}	2.60×10^{1}	13
14	O - 3	0.17	0.30	125	178	4.6		1.87×10^{6}	1.47×10^{-7}	1.36×10^{-7}		1.85×10^{6}	1.81×10^{5}	4.26×10^{3}	7.20×10^{1}	14
15	O - 4	0.13	0.51	62	185	4.7		1.12×10^{6}	2.80×10^{-7}	4.18×10^{-7}		1.07×10^{6}	4.38×10^{5}	3.35×10^{3}	7.60×10^{1}	15
16	O - 5	0.10	0.29	67	90	4.9		1.74×10^{6}	1.46×10^{-7}	1.76×10^{-7}		1.73×10^{6}	1.42×10^{5}	1.66×10^{3}	5.30×10^{1}	16
17	O - 6	0.10	0.22	82	160	4.8		5.48×10^{6}	1.12×10^{-7}	2.28×10^{-7}		5.46×10^{6}	1.48×10^{5}	6.72×10^{2}	4.40×10^{1}	17
18	O - 7	0.12	0.40	74	158	4.7		8.82×10^{6}	1.45×10^{-7}	2.35×10^{-7}		8.64×10^{6}	1.62×10^{5}	2.44×10^{3}	5.60×10^{1}	18
19	O - 8	0.11	0.72	75	190	4.9		2.13×10^{6}	1.92×10^{-7}	3.98×10^{-7}		2.00×10^{6}	1.17×10^{5}	1.06×10^{3}	6.10×10^{1}	19
20	O - 9	0.11	0.27	39	170	4.8		5.14×10^{6}	1.60×10^{-7}	1.70×10^{-7}		5.12×10^{6}	2.42×10^{5}	6.34×10^{3}	2.00×10^{1}	20
21	O - 10	0.10	0.25	43	159	4.8		6.15×10^{6}	9.23×10^{-8}	1.22×10^{-7}		6.14×10^{6}	7.64×10^{5}	2.10×10^{3}	2.50×10^{1}	21
22	O - 11	0.10	0.36	90	145	4.8		1.32×10^{6}	1.77×10^{-7}	8.79×10^{-7}		1.31×10^{6}	1.02×10^{5}	1.52×10^{3}	1.26×10^{2}	22
23	O - 12	0.11	0.28	63	80	4.3		2.81×10^{6}	1.83×10^{-7}	2.40×10^{-7}		2.79×10^{6}	1.50×10^{5}	3.20×10^{3}	3.88×10^{1}	23
24	O - 13	0.13	0.29	41	110	4.4		2.76×10^{6}	7.19×10^{-8}	1.41×10^{-7}		2.74×10^{6}	1.03×10^{5}	1.51×10^{3}	3.20×10^{1}	24
25	O - 14	0.20	0.26	60	90	4.5		4.59×10^{6}	1.37×10^{-7}	2.05×10^{-7}		4.58×10^{6}	1.39×10^{5}	3.23×10^{3}	2.80×10^{1}	25
26	O - 15	0.10	0.39	61	76	4.4		6.38×10^{6}	1.27×10^{-7}	1.30×10^{-7}		6.25×10^{6}	1.23×10^{5}	1.07×10^{3}	3.40×10^{1}	26
27	O - 16			64	72				1.65×10^{-7}	2.02×10^{-7}			5.04×10^{5}	2.01×10^{3}	3.00×10^{1}	27
28	O - 17	0.18	0.52	100	151	4.4		3.43×10^{6}	1.08×10^{-7}	2.28×10^{-7}		3.30×10^{6}	2.49×10^{5}	6.90×10^{2}	5.12×10^{1}	28
29	O - 18	0.11	0.63	88	142	4.7		2.51×10^{6}	1.51×10^{-7}	3.28×10^{-7}		2.47×10^{6}	2.76×10^{5}	1.32×10^{3}	7.80×10^{1}	29
30	O - 19	0.11	0.41	110	180	4.8		3.96×10^{6}	1.49×10^{-7}	3.47×10^{-7}		3.91×10^{6}	1.26×10^{5}	1.18×10^{3}	6.10×10^{1}	30
31	O - 20	0.14	0.44	68	77	4.3		5.40×10^{6}	8.58×10^{-8}	1.20×10^{-7}		5.24×10^{6}	1.51×10^{5}	8.94×10^{2}	8.26×10^{1}	31
32	O - 21	0.11	0.32	37	96	4.3		1.53×10^{6}	1.27×10^{-7}	9.05×10^{-8}		1.80×10^{6}	3.12×10^{5}	3.14×10^{3}	1.60×10^{0}	32
33	O - 22	0.11	0.30	60	70	4.4		1.74×10^{6}	1.43×10^{-7}	1.87×10^{-7}		1.72×10^{6}	1.86×10^{5}	2.00×10^{3}	1.10×10^{1}	33
34	O - 23	0.14	0.34	48	50	4.3		1.02×10^{6}	1.36×10^{-7}	1.25×10^{-7}		5.87×10^{6}	2.84×10^{5}	4.52×10^{3}	2.40×10^{1}	34
35	O - 24	0.11	0.24	43	48	4.2		6.96×10^{6}	1.49×10^{-7}	1.04×10^{-7}		6.93×10^{6}	2.87×10^{5}	2.12×10^{3}	0.00×10^{0}	35
36																36
37																37
38	P - 14	0.17	0.62	95	138	4.5		6.45×10^{6}	2.14×10^{-7}	4.43×10^{-7}		6.34×10^{6}	9.55×10^{5}	1.18×10^{3}	1.25×10^{2}	38
39	P - 16	0.12	0.28	80	100	4.5		5.27×10^{6}	2.32×10^{-7}	3.56×10^{-7}		5.25×10^{6}	2.23×10^{5}	1.91×10^{3}	1.11×10^{2}	39
40	P - 17			64	72				1.18×10^{-7}	1.51×10^{-7}			8.69×10^{5}	1.11×10^{3}	1.61×10^{1}	40
41	P - 22	0.16	0.33	78	103	4.3		2.59×10^{6}	1.65×10^{-7}	2.52×10^{-7}		2.49×10^{6}	3.83×10^{5}	8.30×10^{2}	8.30×10^{1}	41
42																42
43																43
44																44
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49																49
50																50
51																51
52																52

A Cml C 4-10
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Fig. C.7—King shot, stations N, O, and P.

KING

DATA SHEET

	Sample	[illegible] (μ)	[illegible]	[illegible] (μ)	[illegible] (μ)	σ_g	β/cm.²	α/cm.²	γ/cm.²	β/cm.² (.1 - 1μ)	β/cm.² (1 - 10μ)	β/cm.² (10 - 100μ)	β/cm.² (100 μ -)
1													
2	R_n-1	0.11	0.35	90	155	4.6	8.44 x 10^5	5.62 x 10^{-1}	9.73 x 10^{-4}	8.17 x 10^5	2.28 x 10^4	3.90 x 10^3	3.56 x 10^2
3	R_n-2	0.10	0.22	41	118	4.6	1.06 x 10^6	5.55 x 10^{-1}	1.07 x 10^{-3}	1.06 x 10^6	3.41 x 10^4	2.74 x 10^3	3.32 x 10^2
4	R_n-3	0.14	0.36	80	92	4.4	1.08 x 10^6	1.79 x 10^{-1}	3.00 x 10^{-4}	1.07 x 10^6	1.21 x 10^4	1.40 x 10^3	9.84 x 10^1
5	R_n-4	0.10	1.97	98	130	4.7	1.52 x 10^5	4.18 x 10^{-1}	8.79 x 10^{-4}	1.44 x 10^5	6.22 x 10^3	1.84 x 10^3	2.48 x 10^2
6	R_n-5	0.12	0.42	122	158	4.8	4.75 x 10^5	2.88 x 10^{-1}	7.01 x 10^{-4}	4.70 x 10^5	2.83 x 10^3	1.13 x 10^3	2.19 x 10^2
7	R_n-6	0.19	0.84	88	125	4.4	3.31 x 10^5	3.23 x 10^{-1}	6.43 x 10^{-4}	3.32 x 10^5	1.68 x 10^4	2.52 x 10^3	1.18 x 10^2
8	R_n-7	0.16	0.85	68	80	4.3	2.20 x 10^5	1.78 x 10^{-1}	2.95 x 10^{-4}	2.08 x 10^5	9.61 x 10^3	1.87 x 10^3	6.78 x 10^1
9	R_n-8			79	90			3.67 x 10^{-1}	6.01 x 10^{-4}		6.44 x 10^3	2.53 x 10^3	1.34 x 10^2
10	R_n-9	0.12	0.31	49	75	4.3	1.75 x 10^5	7.58 x 10^{-1}	8.26 x 10^{-4}	1.73 x 10^5	1.90 x 10^4	1.29 x 10^3	1.38 x 10^1
11	R_n-10	0.11	0.34	60	67	4.3	5.70 x 10^5	1.97 x 10^{-1}	2.28 x 10^{-4}	5.53 x 10^5	1.17 x 10^4	2.79 x 10^3	1.20 x 10^1
12	R_n-11	0.13	1.24	63	72	4.3	2.01 x 10^5	1.96 x 10^{-1}	2.36 x 10^{-4}	1.77 x 10^5	2.15 x 10^4	2.54 x 10^3	2.52 x 10^1
13	R_n-12			64	76			2.16 x 10^{-1}	3.23 x 10^{-4}		8.96 x 10^3	2.98 x 10^3	5.02 x 10^1
14	R_n-13	0.16	0.39	118	152	4.6	5.01 x 10^5	4.49 x 10^{-1}	1.05 x 10^{-3}	4.88 x 10^5	1.12 x 10^4	1.98 x 10^3	3.30 x 10^2
15	R_n-14	0.33	0.64	86	103	4.0	5.59 x 10^5	3.64 x 10^{-1}	6.22 x 10^{-4}	5.46 x 10^5	1.08 x 10^4	2.18 x 10^3	2.04 x 10^1
16	R_n-15			68	73			2.32 x 10^{-1}	3.40 x 10^{-4}		9.34 x 10^3	1.85 x 10^3	6.20 x 10^1
17	R_n-16	0.10	0.27	80	110	4.6	4.90 x 10^6	9.17 x 10^{-1}	4.30 x 10^{-4}	4.89 x 10^6	2.16 x 10^3	1.44 x 10^3	1.40 x 10^2
18	R_n-17	0.11	0.26	82	120	4.6	3.53 x 10^6	1.90 x 10^{-1}	3.28 x 10^{-4}	3.52 x 10^6	1.74 x 10^4	1.94 x 10^3	9.90 x 10^1
19	R_n-18												
20	R_n-19	0.12	0.40	98	152	4.7	6.26 x 10^5	9.45 x 10^{-1}	1.88 x 10^{-4}	6.27 x 10^5	6.02 x 10^3	1.07 x 10^3	5.30 x 10^1
21	R_n-20	0.10	0.49	115	150	4.8	6.18 x 10^5	4.27 x 10^{-1}	2.48 x 10^{-4}	6.02 x 10^5	1.90 x 10^4	1.58 x 10^3	2.31 x 10^2
22	R_n-21	0.13	0.35	74	98	4.4	6.35 x 10^5	1.06 x 10^{-1}	1.74 x 10^{-4}	6.32 x 10^5	2.03 x 10^3	8.90 x 10^2	4.16 x 10^1
23	R_n-22	0.10	0.36	135	210	5.0	6.44 x 10^5	2.14 x 10^{-1}	8.11 x 10^{-4}	6.40 x 10^5	2.40 x 10^3	1.02 x 10^3	7.26 x 10^2
24	R_n-23	0.14	0.36	128	170	4.7	7.03 x 10^5	2.38 x 10^{-1}	4.85 x 10^{-4}	7.01 x 10^5	2.32 x 10^3	1.10 x 10^3	1.48 x 10^2
25	R_n-24	0.11	0.41	100	400	5.2	6.46 x 10^5	2.91 x 10^{-1}	1.04 x 10^{-4}	6.38 x 10^5	6.18 x 10^3	1.72 x 10^3	1.08 x 10^2
26													
27													
28	R_s-1	0.13	0.30	49	67	4.3	9.16 x 10^6	5.81 x 10^{-1}	6.17 x 10^{-4}	9.06 x 10^6	8.94 x 10^4	1.15 x 10^4	8.40 x 10^1
29	R_s-2	0.10	0.35	67	95	4.5	1.22 x 10^6	1.57 x 10^{-1}	2.21 x 10^{-4}	1.21 x 10^6	1.12 x 10^4	1.92 x 10^3	6.40 x 10^1
30	R_s-3	0.10	0.56	49	70	4.4	6.32 x 10^5	1.58 x 10^{-1}	1.76 x 10^{-4}	5.90 x 10^5	3.82 x 10^4	3.26 x 10^3	2.60 x 10^1
31	R_s-6	0.11	0.38	56	72	4.4	1.97 x 10^6	2.83 x 10^{-1}	3.61 x 10^{-4}	1.93 x 10^6	4.35 x 10^4	4.95 x 10^3	2.40 x 10^1
32	R_s-8	0.10	0.32	105	137	4.8	1.35 x 10^6	1.83 x 10^{-1}	3.91 x 10^{-4}	9.97 x 10^5	1.18 x 10^4	2.76 x 10^2	1.25 x 10^2
33	R_s-9			120	165			2.26 x 10^{-1}	5.28 x 10^{-4}		8.21 x 10^3	1.11 x 10^3	1.54 x 10^2
34	R_s-10	0.10	0.27	112	145	4.8	2.40 x 10^6	3.09 x 10^{-1}	6.80 x 10^{-4}	2.38 x 10^6	3.07 x 10^4	1.25 x 10^3	2.25 x 10^2
35	R_s-11	0.12	0.41	75	112	4.5	1.26 x 10^6	2.94 x 10^{-1}	4.73 x 10^{-4}	1.23 x 10^6	2.32 x 10^4	3.40 x 10^3	1.41 x 10^2
36	R_s-12	0.10	0.33	56	64	4.3	1.89 x 10^6	1.81 x 10^{-1}	1.88 x 10^{-4}	1.86 x 10^6	2.65 x 10^4	3.37 x 10^3	6.60 x 10^1
37	R_s-13	0.13	0.28	145	188	4.8	2.87 x 10^6	4.11 x 10^{-1}	1.11 x 10^{-4}	2.86 x 10^6	8.37 x 10^3	2.04 x 10^3	3.03 x 10^2
38	R_s-17	0.15	0.31	75	128	4.5	2.79 x 10^6	1.54 x 10^{-1}	2.43 x 10^{-4}	2.76 x 10^6	2.94 x 10^4	2.24 x 10^3	8.30 x 10^1
39	R_s-20			96	124			8.52 x 10^{-1}	1.88 x 10^{-4}		8.60 x 10^3	2.79 x 10^3	6.00 x 10^2
40	R_s-21	0.20	1.22	83	110	4.3	3.97 x 10^5	6.91 x 10^{-1}	1.31 x 10^{-4}	3.32 x 10^5	1.96 x 10^4	5.18 x 10^3	3.40 x 10^2
41	R_s-22	0.10	1.36	80	92	4.5	3.84 x 10^5	7.54 x 10^{-1}	1.23 x 10^{-4}	3.47 x 10^5	4.14 x 10^4	5.42 x 10^3	3.20 x 10^2
42	R_s-23	0.13	0.42	62	71	4.5	1.38 x 10^6	1.01 x 10^{-1}	1.73 x 10^{-4}	1.35 x 10^6	1.58 x 10^4	1.51 x 10^3	4.80 x 10^1
43	R_s-24	0.14	0.31	64	75	4.5	1.20 x 10^5	5.84 x 10^{-1}	1.03 x 10^{-4}	8.72 x 10^5	1.70 x 10^4	5.57 x 10^3	7.20 x 10^1

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Fig. C.8—King shot, stations R_n and R_s.

KING

DATA SHEET

	Sample	IRD (d)	β srf (c)	γ 100 (c)	KAD (c)			g/cm.²	c/cm.²	v/cm.²		g/cm.² (.1 - 1μ)	g/cm.² (1 - 10μ)	g/cm.² (10 - 100μ)	g/cm.² (100 — μ)
1															
2	S-1			53	208				2.51 x 10⁻⁷	6.26 x 10⁻⁷			3.71 x 10⁴	1.45 x 10³	1.24 x 10²
3	S-2	0.33	0.36	70	130	4.6		2.77 x 10⁶	2.09 x 10⁻⁷	1.25 x 10⁻⁷		2.69 x 10⁶	7.52 x 10⁴	3.35 x 10³	1.32 x 10¹
4	S-3	0.12	0.31	33	106	4.4		3.54 x 10⁶	1.17 x 10⁻⁷	1.28 x 10⁻⁷		3.50 x 10⁶	4.01 x 10⁴	2.79 x 10³	2.28 x 10¹
5	S-5	0.12	0.30	32	103	4.5		1.23 x 10⁶	1.94 x 10⁻⁷	1.03 x 10⁻⁷		1.16 x 10⁶	7.15 x 10⁴	4.81 x 10³	3.73 x 10¹
6	S-7	0.13	0.43	42	127	4.5		1.40 x 10⁶	1.55 x 10⁻⁷	2.01 x 10⁻⁷		1.32 x 10⁶	2.73 x 10⁴	3.80 x 10³	4.30 x 10¹
7	S-8	0.12	0.20	73	138	4.6		2.45 x 10⁶	1.09 x 10⁻⁷	2.92 x 10⁻⁷		2.60 x 10⁶	2.08 x 10⁴	2.36 x 10³	8.56 x 10¹
8	S-9	0.12	0.27	57	84	4.4		4.21 x 10⁶	2.99 x 10⁻⁷	1.85 x 10⁻⁷		4.18 x 10⁶	2.91 x 10⁴	3.06 x 10³	2.98 x 10¹
9	S-10	0.33	0.35	51	146	4.6		2.90 x 10⁶	2.71 x 10⁻⁷	4.13 x 10⁻⁷		2.83 x 10⁶	6.32 x 10⁴	3.70 x 10³	6.80 x 10¹
10	S-16	0.14	0.43	88	103	4.4		2.55 x 10⁶	1.67 x 10⁻⁷	2.85 x 10⁻⁷		2.57 x 10⁶	2.51 x 10³	1.06 x 10³	8.51 x 10¹
11	S-17	0.14	0.29	64	78	4.3		2.22 x 10⁶	1.76 x 10⁻⁷	2.21 x 10⁻⁷		2.20 x 10⁶	1.40 x 10⁴	2.32 x 10³	4.28 x 10¹
12	S-18	0.12	0.26	94	116	4.6		3.16 x 10⁶	2.49 x 10⁻⁷	4.12 x 10⁻⁷		3.17 x 10⁶	8.35 x 10³	1.66 x 10³	1.12 x 10²
13	S-21	0.33	0.30	42	70	4.3		2.72 x 10⁶	3.10 x 10⁻⁷	3.52 x 10⁻⁷		2.70 x 10⁶	1.39 x 10⁴	2.58 x 10³	4.04 x 10¹
14	S-24	0.12	0.25	88	171	4.7		2.96 x 10⁶	1.46 x 10⁻⁷	3.33 x 10⁻⁷		2.93 x 10⁶	2.37 x 10⁴	7.98 x 10²	8.08 x 10¹
15															
16															
17	V-1	0.12	0.28	7.3	33	3.6		9.15 x 10⁸	1.90 x 10⁻²	4.48 x 10⁻⁶		9.00 x 10⁸	1.40 x 10⁴	6.65 x 10²	0.00 x 10⁰
18	V-11	0.33	0.33	8.8	15	3.3		9.06 x 10⁸	2.43 x 10⁻²	4.41 x 10⁻⁶		8.93 x 10⁸	1.59 x 10⁴	1.32 x 10²	0.00 x 10⁰
19															
20															
21	U-1			98	132				7.32 x 10⁻⁷	1.51 x 10⁻³			5.87 x 10³	2.12 x 10³	4.72 x 10²
22	U-10	0.16	0.35	66	74	4.2		1.25 x 10⁶	3.53 x 10⁻⁷	9.04 x 10⁻³		1.21 x 10⁶	3.47 x 10⁴	4.86 x 10³	3.18 x 10²
23	U-17	0.14	0.33	105	125	4.5		2.71 x 10⁶	6.64 x 10⁻⁷	1.38 x 10⁻³		2.66 x 10⁶	4.29 x 10⁴	1.80 x 10³	4.76 x 10²
24	U-22	0.13	0.24	66	80	4.2		7.37 x 10⁶	3.98 x 10⁻⁷	5.59 x 10⁻³		7.35 x 10⁶	1.28 x 10⁴	2.55 x 10³	3.21 x 10²
25	U-23	0.13	0.20	138	134	4.6		3.74 x 10⁶	5.36 x 10⁻⁷	1.37 x 10⁻³		3.71 x 10⁶	2.97 x 10⁴	3.10 x 10³	2.98 x 10²
26	U-24	0.17	0.33	64	78	4.2		3.85 x 10⁶	4.55 x 10⁻⁷	3.94 x 10⁻³		3.83 x 10⁶	1.77 x 10⁴	4.11 x 10³	1.28 x 10²
27															
28															
29	W-6	0.12	0.55	76	94	4.4		5.64 x 10⁶	3.16 x 10⁻⁷	3.13 x 10⁻⁴		5.48 x 10⁶	1.42 x 10⁴	1.81 x 10³	5.20 x 10¹
30	W-15	0.15	0.30	83	86	4.4		2.96 x 10⁶	2.04 x 10⁻⁷	3.24 x 10⁻⁴		2.95 x 10⁶	2.64 x 10⁴	9.02 x 10²	1.01 x 10²
31	W-26	0.14	0.37	76	103	4.4		1.72 x 10⁶	3.90 x 10⁻⁷	6.35 x 10⁻⁴		1.73 x 10⁶	1.82 x 10⁴	3.53 x 10³	1.44 x 10²
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Fig. C.9—King shot, stations S, V, U, and W.

KING

DATA SHEET

	Sample	NMD (μ)	D avg (μ)	$\bar{D}^3$ MD (μ)	MMD (μ)	σ_g		#/cm.²	s/cm.²	v/cm.³		#/cm.² (.1 - 1μ)	#/cm.² (1 - 10μ)	#/cm.² (10 - 100μ)	#/cm.² (100 - μ)	
1																1
2	LLn-1			74	126				5.39×10^{-7}	8.77×10^{-6}				5.58×10^{-2}	2.46×10^{1}	2
3	LLn-2	0.14	0.60	93	211	4.6		1.81×10^{6}	1.55×10^{-7}	3.13×10^{-6}		1.77×10^{6}	6.46×10^{4}	6.51×10^{2}	8.40×10^{1}	3
4	LLn-3	0.22	0.57	40	120	4.5		9.28×10^{5}	5.16×10^{-7}	6.43×10^{-6}		8.67×10^{5}	3.88×10^{4}	2.61×10^{2}	5.11×10^{1}	4
5	LLn-4	0.12	0.33	68	350	4.8		1.46×10^{6}	9.77×10^{-7}	1.86×10^{-6}		1.45×10^{6}	1.25×10^{4}	9.54×10^{2}	2.99×10^{1}	5
6	LLn-5	0.11	0.31	58	98	4.5		1.5×10^{6}	1.23×10^{-7}	2.38×10^{-6}		1.50×10^{6}	1.40×10^{4}	1.29×10^{2}	1.80×10^{1}	6
7	LLn-6	0.16	0.33	38	63	4.1		2.05×10^{6}	1.37×10^{-7}	1.49×10^{-6}		2.04×10^{6}	1.09×10^{4}	1.08×10^{3}	7.23×10^{1}	7
8	LLn-7	0.15	0.70	72	61	4.2		9.45×10^{5}	1.67×10^{-7}	1.05×10^{-5}		1.66×10^{5}	7.09×10^{4}	5.91×10^{3}	1.16×10^{1}	8
9	LLn-8	0.14	0.34	47	62	4.3		1.21×10^{6}	1.44×10^{-7}	2.11×10^{-6}		1.20×10^{6}	9.69×10^{3}	8.56×10^{2}	7.85×10^{1}	9
10	LLn-9			14	73				1.39×10^{-7}	8.73×10^{-6}				2.00×10^{3}	2.00×10^{1}	10
11	LLn-10	0.18	0.42	85	230	4.7		3.36×10^{6}	1.97×10^{-7}	3.25×10^{-6}		2.45×10^{6}	1.01×10^{4}	2.72×10^{2}	5.52×10^{1}	11
12	LLn-11	0.24	0.39	71	105	4.1		2.83×10^{6}	1.96×10^{-7}	3.20×10^{-6}		2.80×10^{6}	2.29×10^{4}	1.92×10^{3}	5.41×10^{1}	12
13	LLn-12	0.12	0.29	56	92	4.4		4.30×10^{6}	2.86×10^{-7}	3.85×10^{-6}		4.26×10^{6}	3.41×10^{4}	4.70×10^{2}	7.60×10^{1}	13
14	LLn-13	0.13	0.35	52	64	4.2		2.97×10^{6}	3.96×10^{-7}	3.49×10^{-6}		2.54×10^{6}	1.80×10^{4}	3.24×10^{3}	7.50×10^{1}	14
15	LLn-14	0.14	0.37	[illegible]	155	4.6		2.01×10^{6}	3.25×10^{-7}	6.42×10^{-6}		1.97×10^{6}	3.64×10^{4}	2.85×10^{2}	[illegible]	15
16	LLn-15	0.11	0.40	62	70	4.2		1.24×10^{6}	2.78×10^{-7}	1.65×10^{-6}		1.20×10^{6}	3.39×10^{4}	[illegible]	4.20×10^{1}	16
17	LLn-16	0.11	0.44	66	143	4.7		8.00×10^{5}	2.53×10^{-7}	4.92×10^{-6}		7.79×10^{5}	1.90×10^{4}	1.92×10^{3}	4.86×10^{1}	17
18	LLn-17	0.11	0.33	63	42	4.4		1.79×10^{6}	1.75×10^{-7}	2.42×10^{-6}		1.76×10^{6}	2.13×10^{4}	1.36×10^{3}	3.36×10^{1}	18
19	LLn-18			66	160				1.56×10^{-7}	2.56×10^{-6}				2.09×10^{3}	3.68×10^{1}	19
20	LLn-19	0.18	0.47	65	42	4.2		2.41×10^{6}	1.74×10^{-7}	2.31×10^{-6}		2.37×10^{6}	1.46×10^{4}	1.04×10^{3}	4.92×10^{1}	20
21	LLn-20			72	140				1.95×10^{-7}	1.38×10^{-6}				1.13×10^{3}	1.03×10^{2}	21
22	LLn-21			58	82				1.75×10^{-7}	4.05×10^{-6}				3.62×10^{3}	3.05×10^{1}	22
23	LLn-23			92	73				1.27×10^{-7}	3.49×10^{-6}				1.75×10^{3}	2.20×10^{1}	23
24	LLn-24			63	49				3.40×10^{-7}	4.88×10^{-6}				2.87×10^{3}	2.40×10^{1}	24
25																25
26																26
27	LLg-5	0.11	0.27	78	170	4.7		1.79×10^{6}	1.13×10^{-7}	2.47×10^{-6}		1.78×10^{6}	1.35×10^{4}	7.95×10^{2}	4.40×10^{1}	27
28	LLg-15			87	107				1.72×10^{-7}	3.01×10^{-6}				1.14×10^{3}	9.10×10^{1}	28
29	LLg-20			84	102				1.66×10^{-7}	3.44×10^{-6}			1.11×10^{4}	8.12×10^{2}	9.35×10^{1}	29

A Cml C 4-10
(27 Mar 47)

Fig. C.10—King shot, stations LL_n and LL_g

APPENDIX D

DERIVATION OF EQUATION FOR VOLUME OF LIQUID IN GROSS-FALL-OUT COLLECTOR

By Philip W. Krey

It is desired to find an expression for the volume of liquid as a function of liquid depth h (Fig. D.1). The line AB, representing the side of the collector, may be expressed as

$$y = mx + b \tag{D.1}$$

The constants may be evaluated by solving the following set of equations

$$\begin{aligned} 10.50m + b &= 0 \\ 12.25m + b &= 11.25 \end{aligned} \tag{D.2}$$

so that we have

$$y = 6.43 \times -67.5 \tag{D.3}$$

or

$$x = 0.156y + 10.5 \tag{D.4}$$

Now the volume of the collector up to the height h is given by

$$V = \int_0^h \pi x^2 \, dy \tag{D.5}$$

Substit... in Eq. D.5 gives

$$V = \int_0^h \pi(0.156y + 10.5)^2 \, dy \tag{D.6}$$

Integration of Eq. D.6 gives

$$V = (2.54 \times 10^{-2})h^3 + 5.15h^2 + (3.46 \times 10^2)h \tag{D.7}$$

which is the desired expression.

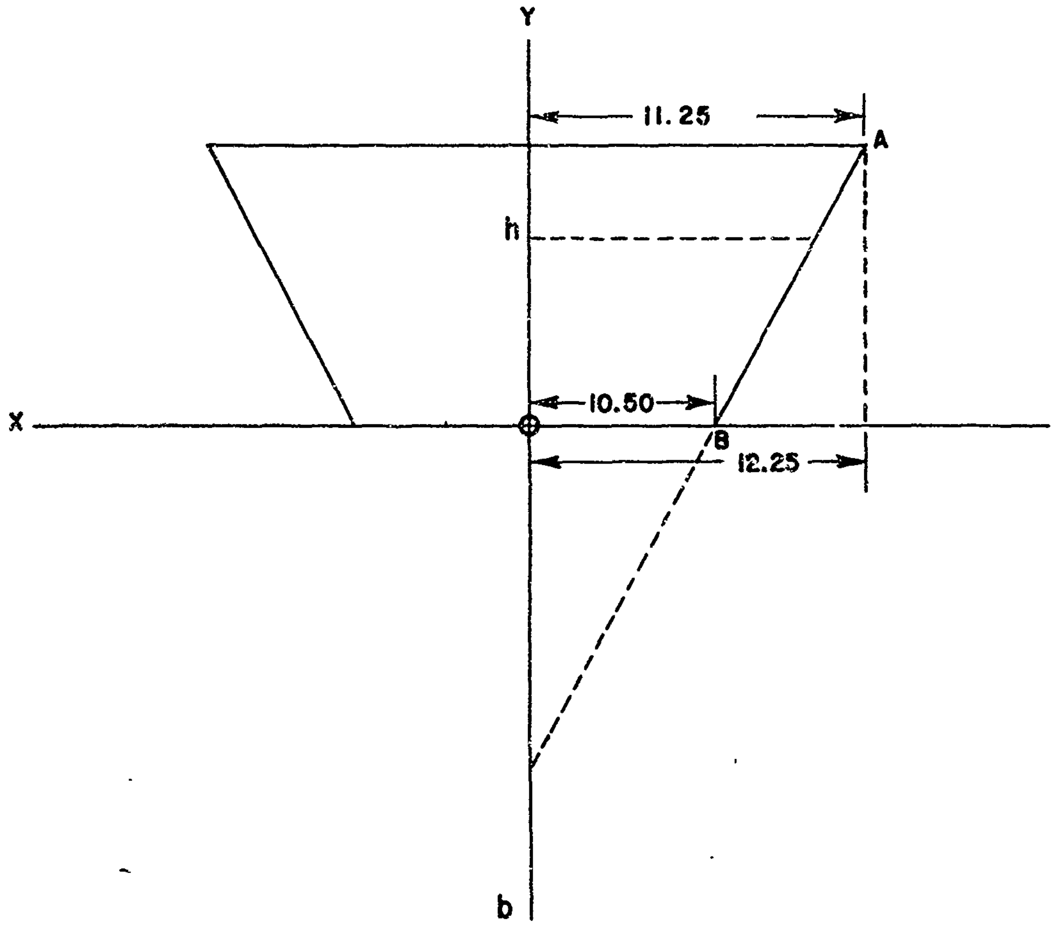

Fig. D.1—Side view of gross-fall-out collector.

2. The machine and its foundation were not watertight. Moisture collected inside the fall-out collector and sometimes condensed on the samples. A change in gasket material and the inclusion of silica gel would eliminate this.

3. Some trays did not center under the sampling opening in the cover; it is possible that fall-out did not occur on portions of the tray sampling surface.

4. The shock wave closed switch S_3 on two collectors, thereby shutting off the machine. It also slightly caved in the top of the same two collectors.

5. The cadmium-plated brass trays corroded excessively.

6. Many Blue Boxes failed to operate the fall-out collectors for Mike shot. Three reasons were advanced for the failures:

(a) The intensity of the light received from the fireball was considerably reduced by the cloud cover, which was quite heavy throughout Mike day.

(b) The rise time of the Mike shot fireball was too slow to actuate the Blue Box phototube.

(c) The Blue Boxes were improperly placed; several were relocated prior to King shot. There were only three Blue Box failures at King shot, at FF_n, FF_s, and Y_s.

7. There may have been cross contamination of trays on the L collector because of a loose gasket between the cover opening and the sampling tray.

E.2.2 Tracerlab Air Monitor

Three Tracerlab air monitors were shipped to the test site. Two of them were out of commission by the time Mike shot occurred. It is assumed that high humidity conditions at Eniwetok and overloaded counting-rate-meter output transformers were the causes of failure.

E.2.3 Gross-fall-out Tubs and Trays

The wash tubs were more useful than the trays for catching gross fall-out. The high walls of the tub caught and held more liquid and solid samples than did the 1-in.-high walls of the flat tray. However, the zinc galvanizing on the tub was not sufficient to keep the inside of the tub from corroding. The insides of all tubs were painted with primer paint before Mike shot. The stainless-steel trays did not corrode appreciably.

2. The machine and its foundation were not watertight. Moisture collected inside the fall-out collector and sometimes condensed on the samples. A change in gasket material and the inclusion of silica gel would eliminate this.

3. Some trays did not center under the sampling opening in the cover; it is possible that fall-out did not occur on portions of the tray sampling surface.

4. The shock wave closed switch S_3 on two collectors, thereby shutting off the machine. It also slightly caved in the top of the same two collectors.

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APPENDIX F

WEIGHT OF INTERMITTENT-FALL-OUT COLLECTOR AND GROSS-FALL-OUT SAMPLES

F.1 WEIGHT OF GROSS-FALL-OUT SAMPLES

The weights of the Mike shot solid gross-fall-out samples which were analyzed for particle-size distribution and radiochemical data are shown in Table F.1. The sample from R station was collected from the flat tray. All other samples were taken from the wash tubs. The samples from W and Y are not the entire amount of fall-out caught by the tubs.

Table F.1—WEIGHT OF MIKE SHOT SOLID GROSS FALL-OUT

Station	Weight, g
R	7.1845
S	14.4303
U	9.8008
V	6.7889
W	12.3165
Y	2.0210
LL	0.5746

F.2 WEIGHT OF INTERMITTENT-FALL-OUT COLLECTOR SAMPLES

Visible heavy fall-out which had been deposited in the intermittent-fall-out collector trays (approximately 16 sq in. in area) was brushed into the glass jars, which were then stoppered and sent back to the Army Chemical Center. The fall-out material was then weighed and sieved through a 325-mesh screen. The fraction that went through the screen, which was calculated to be less than 63 μ, was reweighed. The total weights and the fraction weights under 63 μ are shown in Table F.2. A particle-size distribution analysis was attempted. However, very few particles below 4 μ were found, and it was assumed that these particles adhered to the brush bristles when the fall-out material was being brushed from the trays into the bottle. These small particles should not contribute much to the total weight of the sample.

Table F.2 — WEIGHT OF FALL-OUT COLLECTED BY INTERMITTENT-FALL-OUT COLLECTOR TRAYS AND BRUSHED INTO GLASS JARS

Shot	Station and tray	Total weight, g	Weight of fraction less than 63 μ, g
Mike	K6	0.3454	0.0031
	K7	1.7888	0.194
	K8	0.4415	0.112
	N8	0.899	0.0015
	N9	0.0830	0.0009
	N10	0.1391	0.0021
	N11	0.1525	0.0024
	N12	0.2208	0.0013
	N13	0.1141	0.0015
	N14	0.1190	0.0012
	N15	0.1558	0.0012
	N23	0.1204	0.0014
	N24	0.2136	0.0034
	O6	0.997	0.0032
	O7	0.1163	0.0069
	O8	0.1847	0.0021
	R_n1	0.1645	0.0032
	R_n2	0.3251	0.0049
	R_n3	0.3720	0.0068
	R_n4	0.0543	0.0028
	R_n5	0.1805	0.0016
	R_s4	0.1595	0.0027
	R_s5	0.1431	0.0017
	R_s6	0.0854	0.0008
	S2	0.4696	0.0038
	S3		0.0096
	S4	0.2607	0.0071
	S5	0.1809	0.0045
	S6	0.1340	0.0041
King	J_n6	0.2294	0.0024
	J_n9	0.2055	0.0030
	J_n24	0.3261	0.0220
	M1	0.3330	0.0019

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Part II

AERIAL SURVEY OF GROUND CONTAMINATION

By

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ABSTRACT

The object of this phase of Project 5.4b was to determine the residual gamma activities after each shot and the adequacy of aerial-survey systems in assessing the ground-contamination situation.

Aerial surveys of ground contamination were made daily after each shot in H-19 helicopters using AN/PDR-39 survey meters. Maps and aerial photographs were used for location of position. Air-ground correlation factors were determined by taking the ratio between aerial readings and ground readings made directly below them. It was concluded that with modifications the aerial-survey system used is adequate for assessing ground contamination by atomic- or radiological-warfare weapons.

Residual gamma intensities diagonally upwind from Mike ground zero and doses accumulated in 24-hr periods after Mike shot are given in Tables 4.19 and 4.20.

CHAPTER 1

OBJECTIVE

The objective of Project 5.4b was to conduct the following studies in connection with the surface detonation of a thermonuclear device and an airdrop high-yield fission bomb:

1. To determine the fall-out pattern with its characteristics of activity, particle size, and radiochemical content on the land areas at Eniwetok Atoll.
2. To determine the rate of fall-out at various locations on the Atoll during the first $6\frac{1}{4}$ hr after each shot.
3. To determine the activity of the airborne particulate material near the surface of the ground on Parry Island, Eniwetok Atoll.
4. To obtain data on the activity, particle size, and radiochemical content of the particulate material comprising the cloud from a nuclear detonation by the use of snap samplers in F-84G aircraft.
5. To determine the residual gamma dose rate after each shot and the adequacy of aerial-survey systems in assessing the ground-contamination situation (to be done in cooperation with the Radiological Safety organization).

Part II of this report will cover objective 5. Parts I and III cover objectives 1 to 4.

CHAPTER 2

BACKGROUND

Up to the present no completely satisfactory system has been developed for making aerial surveys of ground contamination by atomic bomb detonations or by radiological-warfare munitions. In general, the two major problems in making aerial surveys of ground contamination are to correlate instrument readings obtained from an aircraft with the actual radiation intensities at the ground surface and to locate precisely on a map or aerial photograph the point on the ground over which each reading is made.

Several different methods of making aerial surveys have been used in the past. David, Hart, and Morgan used a modified G-M survey meter connected with an Esterline-Angus recorder through a d-c amplifier in an L-4 aircraft to measure the radiation intensities over Co^{60}, Cs^{137}, Na^{24}, and Ta^{182} arranged in different patterns on the ground.[1] Measured intensities were in fair agreement with intensities that should be received by the plane at the altitudes flown, as calculated from rather complicated formulas. No attempt was made to determine map locations of the various readings. A training set, AN/PDR-39, which is a modified T1b, connected through a d-c amplifier to an Esterline-Angus recorder was used in a C-45 airplane by Forbes, Lovoff, Dempsey, Redmond, and Nielsen to make surveys of ground contamination on Operation Jangle.[2] Flight patterns were repeated at different altitudes, and the data were extrapolated to the ground. A very rough correlation of intensities with position on the ground was obtained by flying in a series of concentric circles around ground zero to locate the azimuths of fall-out and then flying a series of radials between the two azimuths.

An effort was made by both the Air Force and the Navy on Operation Jangle to more accurately correlate ground locations with instrument readings by using directional instruments and continuously photographing the ground over which the plane was flying.[3] The weight of the equipment used was so great that its use was precluded in light aircraft.

Surveys for uranium in the Colorado Plateau were made in light fixed-wing aircraft and helicopters.[4] Flights were made along predetermined lines, positions being determined visually from maps or aerial photographs. These surveys were made to locate relatively small sources of radiation rather than to plot levels of radiation intensity over large areas.

Features of several of the above methods were incorporated into the procedure for making aerial surveys of ground contamination on Operation Ivy.

CHAPTER 3

OPERATIONS

The standard operating procedure for making the aerial surveys of ground contamination on Operation Ivy is summarized below. Minor modifications to this procedure were made during the operation.

3.1 STANDARD OPERATING PROCEDURE FOR AERIAL SURVEY

3.1.1 Introduction

It is contemplated that aerial surveys of the ground contamination on all the islands of Eniwetok Atoll will be made very soon after the Mike and King shots and at frequent intervals thereafter. The results of these surveys will determine when ground-survey and recovery teams may safely enter each island. An additional purpose in making the aerial surveys is to develop, under Project 5.4b, a practical system for making rapid aerial surveys of ground contamination which can be used by troops in the field.

3.1.2 Personnel and Equipment

The aerial survey will be made from an H-19 helicopter with a T1b survey meter for measuring radiation intensities. The aerial-survey officer will sit next to the pilot, and an instrument man will sit in the passenger space below. Each will carry a clip board with mimeographed data-recording sheets. The survey officer will carry aerial photographs of all islands to be surveyed. Communication between the survey officer and the instrument man will be by the regular interphone system of the helicopter. Communication with the Information Center will be by the established USS Rendova helicopter net.

3.1.3 Flight Plan and Location of Position with Respect to Ground

The position of the helicopter with respect to the ground at all times will be determined with the aid of aerial photographs. Prior to making the first aerial survey, the survey officer will choose and number, from a careful examination of photographs of each island, several points which can be easily located both on the photograph and on the ground. Straight lines will be drawn between these points so that each island is crossed in different directions by these lines. An illustration of a photo marked in this manner is given below.

Line 1-2 will always be the line in the direction of the chain of islands. One copy of each marked photo will be carried by the survey officer. A duplicate copy of each will be retained by the Information Center. Using the aerial photo, the survey officer will direct the pilot to fly accurately over each line at a constant speed of about 30 mph and an altitude of 25 ft when possible. The instrument man will take a series of readings at equally spaced points above each line using the procedure given below.

3.1.4 Procedure for Taking Readings

The instrument man will sit in the seat next to the door of the helicopter and hold the T1b survey meter between his knees. Readings of radiation intensities will be made along each predesignated line at 5-sec intervals on time signals given by the survey officer. The survey officer will give the instrument man prior warning of readings to be made by giving the code name of the island, line number, and altitude. As the helicopter passes over the beginning of the line, the survey officer will say "Read!" The instrument man will make the reading and report it over the interphone. Both will record the reading. The survey officer will continue to say "Read" at 5-sec intervals until the end of the line is reached, each reading being recorded by both the survey officer and the instrument man.

When the intensity is low or is uniform over the whole island, as is expected in most cases, the above procedure can be simplified. The helicopter should first fly over line 1-2 of the island at a speed of about 30 mph. If the intensity is uniform along that line, only one reading need be reported by the instrument man and recorded. If there is a marked variation of intensity along the line, a series of readings should be taken along each line according to the procedure given above.

In order that the M-day survey be made before conditions have become stabilized, the simplified procedure will be used. Only the maximum reading along line 1-2 of each island will be recorded.

In both procedures correction of readings to ground intensity will be as described in the following section.

3.1.5 Correction to Ground Intensity

Measurements made of residual contamination from Greenhouse shots show that intensities measured from an H-19 helicopter at an altitude of 25 ft vary from one-third to one-fifth the intensity as measured with a survey meter 3 ft above the ground. However, the relation between air and ground intensities may differ considerably from this after the Mike and King shots. In order to determine the correct relation, one ground measurement of intensity will be made near the center of at least five different islands on which the maximum reading is less than 5000 mr/hr. These readings should be made with the T1b held 3 ft above the ground and at least 50 ft away from the helicopter. On the basis of these readings the Information Center can correct aerial readings to ground intensities.

In order to avoid tracking contaminated materials into the helicopter, the instrument man will, after making each ground reading, sit in the doorway of the helicopter, remove his bootees, and discard them before reentering the helicopter. For this purpose 10 extra pairs of bootees will be carried in the helicopter making the survey.

3.1.6 Data To Be Sent to Information Center

Immediately after the survey of each island is completed, the following data will be sent in code by radio to the Information Center:

1. Time (not coded).
2. Island.
3. Maximum reading over island.
   Ground reading (if made).

Completed Aerial Survey Forms, 1 and 2, will be turned in to the Information Center immediately after return from the survey trip.

Intensity and island codes will be furnished the survey officer by the Information Center prior to the survey trip. Time of readings will not be coded. Each island will be represented by a two-letter code group. Intensities will be given by a one-letter code for the scale, followed by a two-digit number giving the scale reading. The following is an example of a message to the Information Center:

0830 HA L21 Ground P 07

3.1.7 Plotting of Isodose Lines by Information Center

By comparing readings made from the helicopter with readings at corresponding positions on the ground, the Information Center can determine a factor by which all aerial readings must be multiplied to give ground intensities. Using the $t^{-1.2}$ law, the Information Center may further correct all intensities to the same hour. If these corrected readings are then placed at equal intervals on the proper lines on the aerial photograph or map, isodose lines can easily be drawn in.

3.2 EQUIPMENT

All aerial surveys of ground contamination were made in H-19 helicopters. The initial survey flights after Mike shot were from the aircraft carrier USS Rendova. Subsequent flights were from Parry Island. Gamma-intensity readings were made with AN/PDR-39 survey meters. All meters were calibrated, and different ones were used for each survey. On one of the later surveys an Esterline-Angus recorder was connected through a d-c amplifier to an additional AN/PDR-39 survey meter.

Intermediate-scale maps (1 to 180,000) of Eniwetok Atoll and large-scale (1 to 5,000) aerial photographs of individual islands were used to determine position.

3.3 PERSONNEL

The personnel required for the aerial survey were a survey officer, an instrument man, and a pilot. Since visibility is poor in the passenger compartment of the H-19 helicopter, it was necessary for the survey officer to sit in the copilot's seat in order to direct the survey and determine position. However, space in the copilot's seat was too limited to properly use both the survey meters, the maps, and aerial photographs without interfering with the pilot's control of the helicopter; therefore the survey meters were read by the instrument man in the passenger compartment.

There were no personnel assigned exclusively to making the aerial surveys. Except for four surveys made by the author, different officers and instrument men were drawn for each survey from the monitors in Task Unit 7 (Rad-Safe). Some of the later surveys were made by substitute monitors from other task units. Pilots were drawn from a pool of about 20 Air Force, Navy, and Marine pilots.

CHAPTER 4

RESULTS

The Mike shot was on the surface of Flora (Elugelab), at 0715 hr, 1 November 1952. The surface wind at the time was generally from the east. The approximate distances of the islands of Eniwetok Atoll from Mike ground zero are given in Table 4.1. Figure 4.1 is a map of the Atoll.

The King shot was at an altitude of 1500 ft, at 1130 hr, 16 November 1952, over the ocean north of Yvonne (Runit).

Table 4.1 — APPROXIMATE DISTANCES FROM MIKE GROUND ZERO

Island	Code name	Code letter	Approximate distance from center of island to Mike ground zero, ft
Bogallua	Alice	A	18,000
Bogombogo	Belle	B	14,000
Ruchi	Clara	C	8,000
Cochiti	Daisy	D	6,000
San Ildefonso	Edna	E	4,000
Elugelab	Flora	F	0
Teiteiripucchi	Gene	G	3,500
Bogairikk	Helen	H	5,500
Bogon	Irene	I	8,500
Engebi	Janet	J	16,000
Muzin	Kate	K	21,000
Kirinian	Lucy	L	24,000
Bokonaarappu	Mary	M	31,000
Yeiri	Nancy	N	34,000
Aitsu	Olive	O	37,000
Rujoru	Pearl	P	40,000
Eberiru	Ruby	R	45,000
Aomon	Sally	S	48,000

Table 4.1 — (Continued)

Island	Code name	Code letter	Approximate distance from center of island to Mike ground zero, ft
Biijiri	Tilda	T	50,000
Rojoa	Ursula	U	53,000
Aaraanbiru	Vera	V	55,000
Piiraai	Wilma	W	57,000
Runit	Yvonne (North end)	Y	70,000
Chinieero	Alvin	AA	98,000
Aniyaanii	Bruce	BB	102,000
Chinimi	Clyde	CC	106,000
Japtan	David	DD	111,000
Parry	Elmer	EE	115,000
Eniwetok	Fred	FF	127,000
Igurin	Glenn	GG	117,000
Mui	Henry	HH	114,000
Pokon	Irwin	II	112,000
Ribaion	James	JJ	109,000
Giriinien	Keith	KK	107,000
Rigili	Leroy	LL	84,000

4.1 SURVEY DATA

Tables 4.2 to 4.17 give the results of the aerial surveys made from 1 to 17 November 1952. Since in most cases the level of contamination was fairly constant over each individual island, only the reading over the center of each island is given. Ground intensities may be obtained by multiplying the aerial readings by the average air-ground correlation factor obtained during the survey. Table 4.18 is an example of survey data for an island on which the radiation level was not uniform. Isodose lines from these data are plotted in Fig. 4.2. Each predetermined line was divided into equally spaced divisions on the map or aerial photograph, the number of divisions being determined by the number of aerial intensity readings taken above that line during the survey. The aerial intensity readings were multiplied by the air-ground correlation factor determined for that day to give ground intensities. These ground intensities were then placed by the corresponding divisions on the predetermined lines, and the isodose lines were drawn in.

4.2 AIR-GROUND CORRELATION FACTOR

The air-ground correlation factor is the ratio of the intensity at a point on the ground to the intensity in the helicopter at an altitude 25 ft directly above that point. On islands on which no ground reading was obtained, the aerial reading was multiplied by the average air-ground correlation factor for the day to obtain the ground intensity. The average daily factor varied between 3.0 and 2.0. During the first week after Mike shot, it remained in the vicinity of 2.8. By the end of the second week, it had dropped to around 2.2. No air-ground correlation factors were obtained for King shot. The level of contamination from King shot was low and was obscured by residual Mike activity, except on Yvonne.

(Text continues on page 126.)

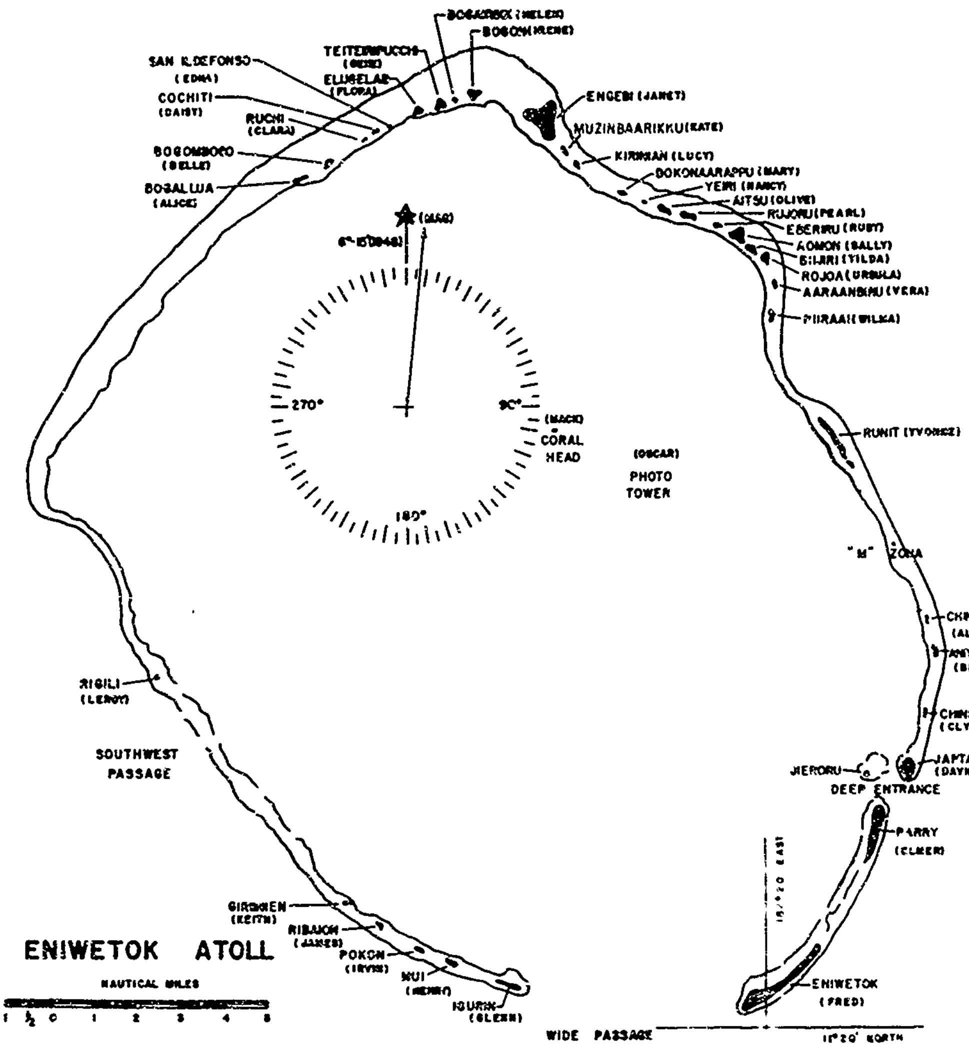

Fig. 4.1—Map of Eniwetok Atoll

Table 4.2 — AERIAL-SURVEY DATA, 1 NOVEMBER 1952 (M-DAY; H-HOUR, 0715; ALTITUDE, 25 FT)

Time	Island	Aerial dose rate, mr/hr	Ground dose rate, mr/hr	Air-ground correlation factor
0729	Fred	0		
0734	Elmer	0		
0735	David	0		
0737	Clyde	0		
0738	Bruce	0		
0740	Alvin	0		
0743	Yvonne	0–4,000	12,000†	3.0
0800	Wilma	14,000		
0805	*			

*Survey ended because helicopter was contaminated by a muddy, radioactive rain.
†N end of island.

Table 4.3 — AERIAL-SURVEY DATA, 2 NOVEMBER 1952 (M + 1 DAYS; ALTITUDE, 25 FT)

Time	Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
0738	Y	200		
0744	W	1,400	4,200	3.0
0748	V	1,600		
0749	U	2,800	10,000	3.6
0751	T	3,000		
0752	S	3,800		
0752	R	4,000		
0753	P	10,000		
0754	O	10,000		
0754	N	10,000		
0755	M	12,000		
0756	L	13,000		
0756	K	13,000		
0757	J	19,000		
0805	A	14,000		
0805	B	16,000		
0806	C	16,000		
0825*	LL	120		

*Reading made at 50 ft.

Table 4.4—AERIAL-SURVEY DATA, 3 NOVEMBER 1952 (M + 2 DAYS; ALTITUDE, 25 FT)

Time	Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
0840	Y	100	200*	2.0
0846	W	700	1,700	2.4
0849	V	800		
0850	U	1,200	3,000	2.5
0853	T	1,800		
0853	S	2,600		
0854	R	2,100		
0855	P	2,700	8,000	3.0
0858	O	2,400		
0859	N	2,200		
0859	M	2,800		
0900	L	3,200	12,000	3.7
0902	K	4,400		
0903	J	6,000	17,000	2.8
0907	I	10,000	27,000	2.7
0909	H	13,000		
0910	G	36,000		
0916	A	7,000	18,000	2.6
0920	B	8,000		
0921	C	8,000		
				Av. 2.7

*N end of island.

Table 4.5—AERIAL-SURVEY DATA, 1500 TO 1630, 4 NOVEMBER 1952 (M + 3 DAYS; ALTITUDE, 25 FT)

Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
Y	31	100	3.2
W	220		
V	280		
U	800		
T	1,000	2,000	2.0
S	1,000		
R	1,000		
P	1,500		
O	1,500		
N	1,400		
M	1,500		
L	2,000		
K	2,200		
J	3,300		
I	9,000		

Table 4.5 — (Continued)

Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
G	18,000		
E	10,000	26,000	2.6
D	10,000		
C	9,000		
B	10,000		
A	10,000		
LL	30	95	3.2
			Av. 2.8

Table 4.6 — AERIAL-SURVEY DATA, 0730 TO 0830, 5 NOVEMBER 1952 (M + 4 DAYS; ALTITUDE, 25 FT)

Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
Y	28		
W	220		
V	230		
U	600		
T	800		
S	1,100		
R	800		
P	1,200		
O	1,200		
N	1,100		
M	1,500		
L	1,400		
K	1,800		
J	4,000	10,000*	2.5
I	8,000		
H	8,000		
G	12,000		
Crater	14		
E	20,000		
D	6,000		
C	3,400		
B	3,800	10,000	2.6
A	3,000	9,000	3.0
LL	30	100	3.3
			Av. 2.9

*N end of island.

Table 4.7 — AERIAL-SURVEY DATA, 0800 TO 0840, 6 NOVEMBER 1952 (M + 5 DAYS; ALTITUDE, 25 FT)

Island	Aerial reading, mr/hr	Ground intensity, mr/hr
Y	22	
W	210	
V	260	
U	440	
T	600	
R	700	
P	900	
O	1,000	
N	800	
M	1,000	
L	1,800	
K	1,800	
J	2,800	
I		8,000
H	16,000	
E		13,000
D		7,000
C	4,000	
B		6,000
A		5,000
LL		41

Table 4.8 — AERIAL-SURVEY DATA, 0745 TO 0845, 7 NOVEMBER 1952 (M + 6 DAYS; ALTITUDE, 25 FT)

Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
Y	16	50	3.1
W	100		
V	100		
U	200	720	3.6
T	240		
S	380		
R	360		
P	500	1600	3.2
O	500		
N	400		
M	400		
L	800		
K	800		
J	1400	3900	2.8
I	2800	7000	2.5

Table 4.8 — (Continued)

Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
H	2200		
G	3000 – 8000		
Crater	20		
E	7000		
D	2000	5100	2.6
C	1400		
B	1800	4400	2.4
A	1500	3500	2.3
LL	14		
			Av. 2.8

Table 4.9 — AERIAL-SURVEY DATA, 0900 TO 0930, 8 NOVEMBER 1952 (M + 7 DAYS; ALTITUDE, 25 FT)

Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
Y	18		
W	100		
V	120		
U	200	400	2.0
T	240		
S	400	1,000	2.5
R	200		
P	390	800	2.1
O	340		
N	350		
M	420		
L	800	1,600	2.0
K	700		
J	1,200	2,400	2.0
I	1,900	5,000	2.6
H	1,800		
G	6,000	18,000	3.0
Crater	10		
E	6,000		
D	1,800	4,500	2.5
C	1,600		
B	1,400	3,600	2.6
A	1,400		
LL	10		
			Av. 2.4

Table 4.10—AERIAL-SURVEY DATA, 1330 TO 1420, 9 NOVEMBER 1952 (M + 8 DAYS; ALTITUDE, 25 FT)

Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
A	1300	2800	2.2
B	1400		
C	1300	2600	2.0
D	1500	3300	2.2
E	3300		
G	3400	8000	2.4
H	1700		
I	2000	3800	1.9
J	1400	2500	1.8
K	900		
T	200	600	3.0
U	180	400	2.2
V	120		
W	100		
Y	16		
			Av. 2.2

Table 4.11—AERIAL-SURVEY DATA, 0800 TO 0850, 10 NOVEMBER 1952 (M + 9 DAYS; ALTITUDE, 25 FT)

Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
A	900	2200	2.4
B	1000	2400	2.4
C	900	2800	3.1
E	3000	8800	2.9
G	3500		
J	1000	2400	2.4
K	500		
L	500		
M	410	1000	2.4
N	300	850	2.8
O	340	750	2.2
P	380	800	2.1
R	280		
S	200		
T	200	500	2.5
U	140	340	2.4
V	100		
W	60		
Y	10	24	2.4
			Av. 2.5

Table 4.12 — AERIAL-SURVEY DATA, 0730 TO 0830, 12 NOVEMBER 1952 (M + 11 DAYS; ALTITUDE, 25 FT)

Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
W	40	90	2.3
V	90		
U	90	200	2.2
T	110		
S	160		
R	140		
P	200	480	2.4
O	180	440	2.4
N	160		
M	240	600	2.5
L	360		
K	300		
J	900	1500	1.7
I	1000	2400	2.4
H	800		
G	1400		
Crater	500		
E	1600		
D	700	2200	3.1
C	700		
B	900	1950	2.2
A	800	2100	2.6
			Av. 2.4

Table 4.13 — AERIAL-SURVEY DATA, 1630 TO 1700, 12 NOVEMBER 1952 (M + 11 DAYS; ALTITUDE, 25 FT)

Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
Y	10		
W	50	130	2.6
V	70		
U	100	230	2.3
T	140		
S	300	530	1.8
R	260		
P	240	530	2.2
O	240	530	2.2
N	240		

Table 4.13 — (Continued)

Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
M	270	700	2.6
L	430		
K	430		
J	690	1500	2.2
A	800	1900	2.4
B	770	2100	2.7
C	690		
D	1000	2400	2.4
E	2500		
G			
H	1200		
I	1400	3000	2.1
			Av. 2.3

Table 4.14 — AERIAL-SURVEY DATA, 1630 TO 1710, 14 NOVEMBER 1952 (M + 13 DAYS; ALTITUDE, 25 FT)

Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
A	800	1400	1.7
B	1000		
C	1000		
D	1000		
E	2200		
G	3200		
H	1200		
I	1000	2400	2.4
J	800		
K	460		
L	410		
M	280		
N	240		
O	280		
P	260		
R	190		
S	260		
T	130	280	2.2
U	120	210	1.8
V	60		
W	40		
			Av. 2.0

Table 4.15—AERIAL-SURVEY DATA, 1015 TO 1045, 15 NOVEMBER 1952 (M + 14 DAYS; ALTITUDE, 25 FT)

Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
W	26		
V	31		
U	130	190	2.1
T	130	270	2.1
S	120		
R	110		
P	160		
O	160		
N	140		
M	200	440	2.2
L	400	900	2.3
K	400		
J	600	1400	2.3
I		2200	
H	1600		
G	1900		
E	2200		
D	1000		
C	800		
B	900		
A	850		
			Av. 2.2

Table 4.16—AERIAL-SURVEY DATA, 1210 TO 1255, 16 NOVEMBER 1952 (M + 15 DAYS; K-DAY; ALTITUDE, 25 FT)

Time	Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
1210	Y	0–4000		
1221	W	42		
1223	V	48		
1224	U	80		
1225	T	90	220	2.4
1227	S	170		
1228	R	150		
1229	P	180	380	2.1
1230	O	180	390	2.2
1232	N	160		
1233	M	280		
1238	L	340		
1239	K	330		
1239	J	480–700		
1240	I	1000	2000	2.0
1242	H	1000		
1243	G	2400		
1243	Mike crater	0		
1244	E	2000		
1245	D	800	1600	2.0
1246	C	400		
1246	B	700	1600	2.3
1248	A	750		
1255	MM	1		
				Av. 2.2

Table 4.17—AERIAL-SURVEY DATA, 0805 TO 0942, 17 NOVEMBER 1952 (M + 16 DAYS; K + 1 DAY; ALTITUDE, 25 FT)

Time	Island	Aerial reading, mr/hr	Ground intensity, mr/hr	Air-ground correlation factor
0805	Y	320		
0807	W	28		
0808	V	34		
0810	U	70	150	2.1
0813	T	90	200	2.2
0814	S	160		
0815	R	50		
0816	P	160		
0817	O	150		
0817	N	130		
0818	M	190	410	2.2
0825	L	260		
0826	K	310		
0835	J	430	900	2.1
0937	I	800		
0938	H	600		
0938	G	1600		
0940	E	1200	2800	2.3
0940	D	700		
0941	C	420		
0942	B	500		
0942	A	440		
			Av	2.2

Table 4.18—AERIAL SURVEY OF JANET (ENGEBI), 0810, 7 NOVEMBER 1952 (M + 6 DAYS; ALTITUDE, 25 FT)

Aerial reading, mr/hr			
Line 12	Line 23	Line 34	Line 45
950	1600	1200	900
1200	1700	1300	1100
1300	1600	1400	1300
1400	1500	1300	1400
1500	1400	1100	1600
1600	1300		1700
			1600

Instrument: AN/PDR-39.

Aerial readings at equally spaced points along predesignated lines.

Location of ground reading: near center of island, directly below aerial reading of 1400 mr/hr.

Ground reading (mr/hr): 3900.

Air-ground correlation factor determined from above readings: 2.8.

4.3 GAMMA DOSE RATES AT DISTANCES FROM GROUND ZERO

Table 4.19 gives the gamma dose rate at different distances diagonally upwind from ground zero at various times after the Mike detonation. Since levels of radiation were too high at M + 1 hr to obtain readings closer than [illegible] ft from ground zero without overexposing personnel, values of intensity at M + 1 hr are extrapolated from readings taken at greater distances and from comparative readings obtained later. Intensities are interpolated to correspond to multiples of 10,000 ft from ground zero.

Table 4.19—RESIDUAL GAMMA DOSE RATES (ROENTGENS PER HOUR) SOUTHEAST FROM MIKE GROUND ZERO

Distance from ground zero, ft	Time, hr						
	M + 1	M + 24	M + 48	M + 72	M + 96	M + 120	M + 144
10,000	1200	120	25	22	20	8	7
20,000	500	50	12	7	7	6	3
30,000	300	35	8	4	4	3	1.5
40,000	250	30	8	4	3.5	2.5	1.5
50,000	140	10	5	2	2	1.5	0.7
70,000	[illegible]	0.6	0.2	0.1	0.1		

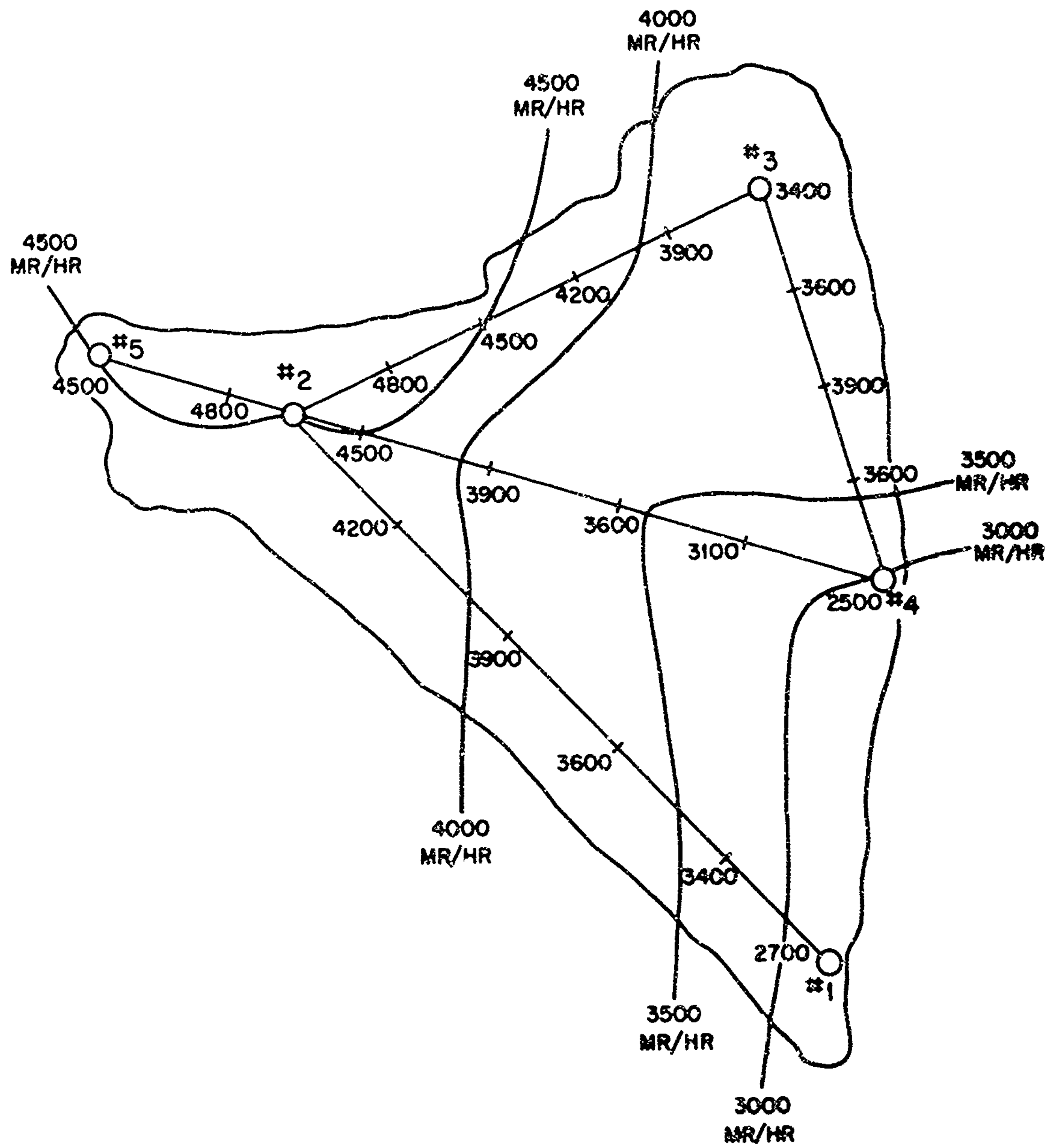

Fig. 4.2—Gamma intensities on Janet (Engebi) at 0810, 7 November 1952 (M+6).

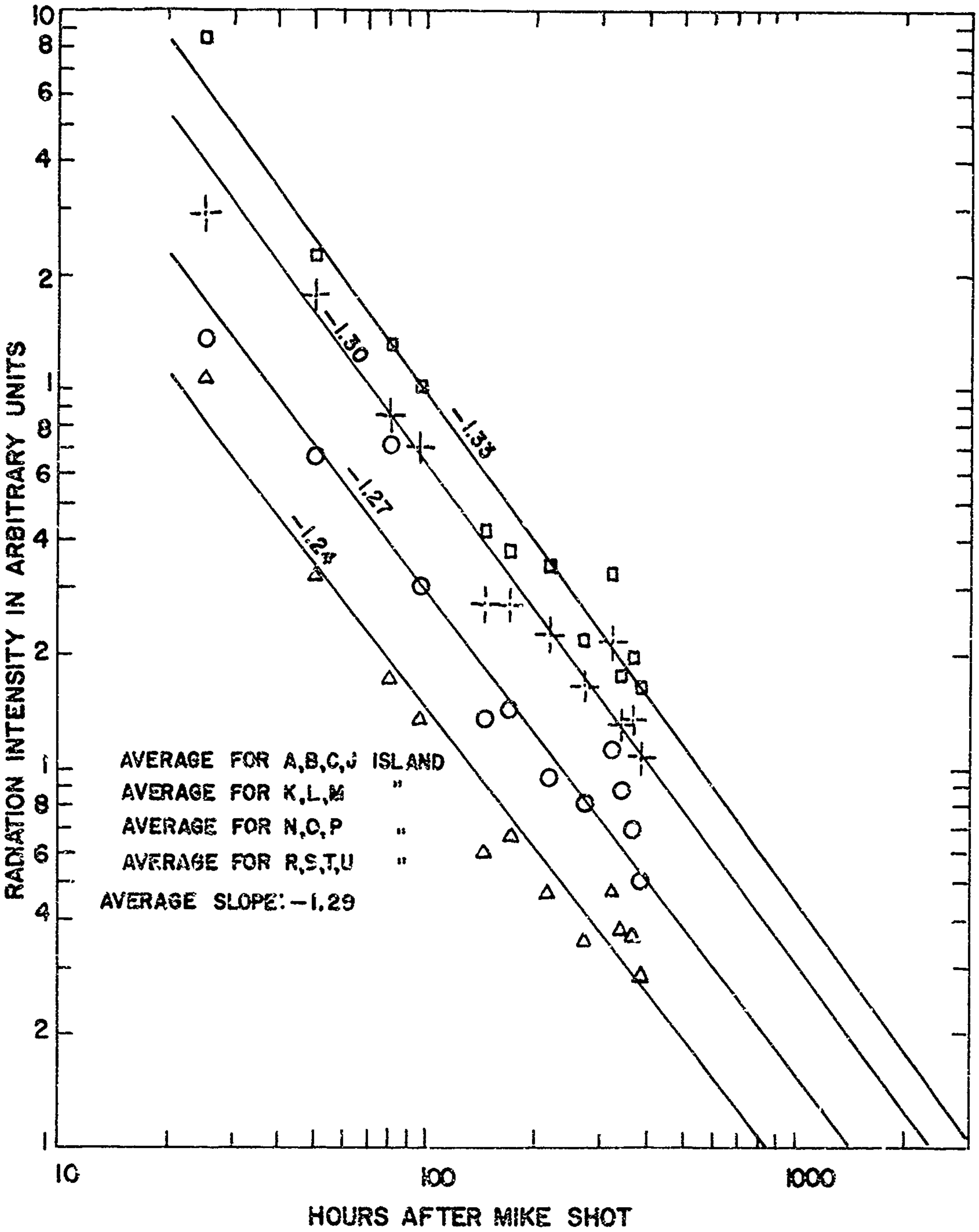

Fig. 4.3—Decay of residual gamma activity after Mike shot.

4.4 GAMMA DOSES DURING 24-HR PERIODS

Table 4.20 gives the approximate accumulated doses during different 24-hr periods from residual radiation southeast from ground zero after Mike shot. In some cases radiation intensities were reduced considerably by weathering during a 24-hr period. Since it is not known during what part of any given 24-hr period the major part of the weathering took place, the calculated doses in Table 4.20 may, in some cases, vary considerably from the actual ones. In obtaining the figures in Table 4.20, it was assumed that any weathering took place uniformly during the period.

Table 4.20 — APPROXIMATE GAMMA DOSES (ROENTGENS) FOR 24-HR PERIODS AFTER MIKE SHOT

Distance from ground zero, ft	24-hr periods					
	1st	2d	3d	4th	5th	6th
10,000	7,000	1,000	550	500	250	180
20,000	3,000	450	200	220	150	100
30,000	1,800	300	120	100	80	50
40,000	1,500	270	120	90	70	45
50,000	700	150	75	48	40	25
70,000	40	7	3	2		

4.5 DECAY OF RESIDUAL GAMMA INTENSITIES

The average decrease in residual gamma intensity after Mike shot on 14 islands is plotted in Fig. 4.3. This decrease is due both to radioactive decay and to weathering effects. For convenience intensities are averaged for groups of islands with approximately the same radiation levels. The slopes of these curves on log paper vary between −1.24 and −1.33, averaging −1.29.

4.6 RESULTS WITH THE ESTERLINE-ANGUS RECORDER

The AN/PDR-39 was connected through a d-c amplifier to an Esterline-Angus recorder on one of the aerial surveys. At flying speeds of 30 mph or more, it was found that because of the short times of the flights over the smaller islands the recorder did not have time to reach the maximum intensity. Another difficulty was that, over islands on which radiation intensities varied considerably, changing the scale on the AN/PDR-39 interrupted the trace on the recorder.

4.7 RADIATION DOSES RECEIVED BY PERSONNEL MAKING AERIAL SURVEYS

The maximum gamma dose received by personnel on any aerial survey was 0.7 r. In most cases the dose was below 0.5 r per survey during the first week after Mike shot and below 0.2 r per survey during the second week.

CHAPTER 5

DISCUSSION

Some inaccuracies and inconsistencies were introduced into the survey data by the nature of the system used to obtain the data, by the manner in which personnel followed the outlined procedure, and by the geography of the terrain surveyed. For example, the intensities measured over Alice, Belle, and Clara, on 4 November (M + 3 days), were considerably higher than those measured the previous day for these three islands. Obviously the measurements were in error on one or both of these days for the islands in question. The degree of accuracy of the results and the sources of error are discussed below.

5.1 ACCURACY OF THE SURVEY DATA

Since all instruments were calibrated prior to the Mike shot, the actual ground readings taken at least 50 ft away from the helicopter were probably within the ±15 per cent accuracy to be expected from an AN/PDR-39. It was found that readings obtained by a person standing a few feet away from the helicopter or holding the instrument out of the door while the helicopter was on the ground averaged about 15 per cent lower than readings obtained at least 50 ft away from the helicopter.

The aerial readings, and hence any air-ground correlation factors determined from them, were probably, in some cases, off by as much as ±50 per cent. In the case of the air-ground correlation factors, any such errors were reduced by averaging them for each survey before applying them. However, even though the average correlation factor might have been correct, it would, of course, give an erroneous ground intensity when applied to an incorrect aerial reading. Errors as high as ±50 per cent probably occurred only when the personnel making the survey did not follow the outlined survey procedure correctly. It is believed that, in most cases, the accuracy of the results was better than ±30 per cent.

The ±30 per cent errors apply only to the special conditions of these surveys. For radiation fields approaching infinite-plane radiation, such as those occurring in atomic-warfare tests on large land areas, the accuracy of this method should be better than ±20 per cent.

5.2 SOURCES OF ERROR

The ±15 per cent error to be expected from the T1b survey meter was mentioned above. Another factor causing errors in the survey data was the nature of the terrain surveyed. The radiation intensities at points above the smaller islands differed from the intensities that would be received at the same altitudes above an infinite plane contaminated to the same degree. Differences in the sizes of the islands and variations in altitude affected the solid angle from which the radiation was received. Diverse estimations of altitude by different

pilots also gave rise to variations in the results. Errors of this type were reduced by making the surveys at a very low altitude (25 ft).

Changing the personnel making the survey each day resulted in some of the surveys being made by persons not thoroughly familiar with the procedure to be used. Survey personnel were designated by Rad-Safe on the afternoon of the day before the survey was to be made. These persons were requested to read the standard operating procedure for aerial surveys and to be present for a 30-min briefing just before the survey started. In some cases the standard operating procedure was not read, and a 5- or 10-min briefing was the only familiarity the survey personnel had with the procedure. After some of the surveys it was found that flights over some of the islands were made at an altitude of 10 ft to get better readings or at a 50-ft altitude over the hotter islands to reduce exposure to radiation. In a few cases ground intensities were read by merely holding the instrument from the door of the helicopter, resulting in lower readings. On one survey no aerial readings were made over islands on which ground intensities were read; so no correlation factor could be determined for that day. In some cases corrections could be made for such procedure variations, but this was not always possible.

On very small islands, such as Helen, the response time of the T1b was too slow to record the maximum intensity over the island if the flight over it was at too great a speed.

5.3 THE EFFECT OF DUST BLOWN UP BY THE HELICOPTER ROTORS

Because of the sandy nature of the islands of Eniwetok Atoll, it was thought by some persons that the contaminated dust blown up by the helicopter rotors would constitute a health hazard and would affect intensity readings. This was found not to be the case. The only cases of contamination of helicopters were by fall-out shortly after Mike shot and by personnel tracking contamination into the helicopter when they neglected to remove their bootees before entering. The amount of dust and sand kicked up by the helicopter was negligible when flying at altitudes of over 10 ft. Even during landing and taking off, very little dust came into the helicopter, and no change in radiation level resulting from dust being blown away could be detected. On some surveys as many as 10 landings were made without causing any detectable contamination of the helicopter (except on the wheels).

5.4 EQUIPMENT USED IN AERIAL SURVEYS

Aerial surveys of ground contamination could be facilitated by using equipment different from that used at Operation Ivy. An H-13 helicopter would be preferable to the H-19. Visibility is much better from the H-13, which would make location of position easier. There is room in the H-13 for the instruments to be operated by the survey officer, thus eliminating the need for a separate instrument man. A survey meter with a faster response time than the AN/PDR-39 would be desirable. A single logarithmic scale would be much better than five linear scales. A recorder is needed with a much faster response time than that of the Esterline-Angus recorder. A probe suspended below the helicopter would eliminate the need of landing to obtain ground readings. Aerial photographs used in making surveys should be about 1 to 20,000 scale rather than 1 to 5,000.

The question as to whether helicopters or fixed-wing aircraft are more suitable for making aerial surveys of ground contamination from atomic- or radiological-warfare munitions has frequently arisen. Experience indicates that helicopters are more amenable for locating position with accuracy than fast flying fixed-wing aircraft. Although it is relatively simple to determine general position and to plot a course in a fixed-wing aircraft, location of the exact point over which the plane is flying at a given instant of time to within 100 yd is a much more difficult and time-consuming matter. In flying over a closely spaced (100 to 200 yd) predetermined grid dependent upon accurate location of numerous small

terrain features on both aerial photographs and the ground, the time lost in locating these features, making false runs, and making turns at the end of each run in a fixed-wing aircraft would make the survey take much longer than would be the case with a helicopter. Also the determination of an air-ground correlation factor is much less accurate in a fixed-wing aircraft. Over many types of terrain and over cities, fixed-wing aircraft must fly at much higher altitudes than helicopters. Since an air-ground correlation factor determined for infinite-plane radiation would not apply to relatively small hot spots, completely erroneous intensities might be determined for such areas by aircraft flying at altitudes over 50 ft. For the above reasons it is believed that helicopters are the only suitable aircraft for making accurate aerial surveys of ground contamination of areas of a few square miles extent. If the contaminated area were hundreds of square miles in extent and if position errors of several hundred yards and a lesser degree of accuracy in radiation levels were acceptable, fixed-wing aircraft would be much more suitable than helicopters for making the survey.

CHAPTER 6

CONCLUSIONS

6.1 RESIDUAL GAMMA ACTIVITY

1. Land areas were contaminated to a dangerous degree more than 12 miles upwind from Mike shot. An LD_{100} dose of residual gamma radiation would have been received by a person remaining 10 miles upwind from ground zero for the 24-hr period following Mike shot. Four days after Mike shot, a person would have received an LD_{50}/30 days' dose in 24 hr as far as two miles upwind from ground zero.

2. The level of contamination from King shot was much lower than from Mike shot. The highest gamma intensity found during any aerial survey was about 10r/hr 40 min after the shot.

6.2 AERIAL-SURVEY PROCEDURE

1. The aerial-survey system used is adequate with modifications for accurate navigation. The AN/PDR-39 proved satisfactory as a survey instrument for measuring the dose rate within a limited range of gamma energies. However, there is no assurance that the instrument is sensitive to low-energy scattered radiation.

2. H-13 helicopters are preferable to the H-19 type for making aerial surveys. An accurate altimeter below 300 ft is desirable.

3. The AN/PDR-39 should be replaced by a survey meter with a faster response time and with a single logarithmic scale.

4. The survey meter used should incorporate a probe that could be suspended below the helicopter.

5. A recording device with a response time faster than that of the Esterline-Angus recorder should be used to record the survey data.

6. It is important that aerial surveys be made only by personnel thoroughly trained in the procedures to be used.

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Part III

CLOUD-SAMPLING TECHNIQUES USING SNAP SAMPLERS

By

Michael J. Schumchyk

ABSTRACT

The objective of this phase of Project 5.4b was to collect gas and particulate samples from clouds produced by nuclear detonations at Operation Ivy through the use of the snap sampler in F-84G aircraft and to obtain data on the radiochemical content, activity, and particle size of the particulate material comprising the cloud at sampling altitudes.

From the particulate samples collected and analyzed on Mike shot, the total number of fissions producing the sample collected was on the order of 10^{10} and 10^{11}.

The following R factors were obtained from bag particulate samples: Ce^{144}/Mo^{99}, 0.14; Ba^{140}/Mo^{99}, 1.37; and Sr^{89}/Mo^{99}, 0.57; and, from a filter particulate sample, Ce^{144}/Mo^{99}, 0.97.

The activity data, corrected to H + 1 hr, obtained on the snap-sampler evacuation filters (Mike shot) used when transferring the gas sample from the collecting bags to the shipping containers, ranged from 1.4×10^{3} to 46.8×10^{8} dis/min.

An attempt to develop techniques for obtaining particle-size data from particulate samples in plastic bags was not feasible; therefore no particle size data have been obtained.

The two decay slopes measured on samples, one from the evacuation filters (−2.08) and one from a plastic sampler bag (−2.35), were comparatively higher than decay slopes found from samples obtained at other operations and by other sampling methods.

The King shot samples contained too little radioactivity for analysis.

PREFACE

The purpose of this report is to supplement the preliminary report and to provide final data on particulate samples collected by sampling radioactive clouds produced by nuclear detonations, as stated in Part I of this report.

CHAPTER 1

OBJECTIVE

The objective of this phase of Project 5.4b was to collect gas and particulate samples from clouds produced by nuclear detonations at Operation Ivy through the use of the snap sampler in F-84G aircraft and to obtain data on the radiochemical content, activity, and particle size of the particulate material comprising the cloud at sampling altitudes.

CHAPTER 2

BACKGROUND

The Chemical Corps did particulate sampling of nuclear clouds with cascade impactors installed in structures and drone aircraft at Operation Sandstone.[1]

In preparation for the study of clouds produced at Operation Greenhouse, the Chemical Corps studied methods for the collection of representative samples of particulate and gaseous matter.[2] For AFOAT-1 (USAF) and the Chemical Corps, Tracerlab, Inc., designed the sampling device designated as the "snap sampler."[3] On Operation Greenhouse this sampling device was installed in B-17 drones and used to collect samples of airborne gaseous and particulate matter. On Operation Tumbler-Snapper one snap sampler, as used in Operation Greenhouse, installed in a B-29 aircraft, and one modified snap sampler installed in a F-84G aircraft were used mainly to develop sampling techniques that would be suitable for Operation Ivy. After Operation Tumbler-Snapper the F-84G aircraft with the snap sampler was delivered to Mobile, Ala., where 15 additional F-84G aircraft were similarly instrumented. These 16 aircraft were delivered to Bergstrom Air Force Base, Tex., and participated in Operation Texan, in August 1952, which was a complete dry-run rehearsal for Operation Ivy. These aircraft were then used at Operation Ivy to obtain samples of clouds for analysis of gaseous and particulate matter.

CHAPTER 3

INSTRUMENTATION

3.1 DESCRIPTION

The snap sampler consists essentially of a collapsed polyethylene bag attached to a probe, which extends forward from the nose of an F-84G aircraft. On the intake end of the probe, there is a diffuser with an orifice of such diameter that approximate isokinetic sampling will be obtained. At the other end of the probe, there is a quick-opening sliding-gate valve. An electric circuit tied in with the aircraft power supply is used to open and close the gate valve to start and stop sampling.

As the aircraft flies through the cloud to be sampled, the pilot, by squeezing a trigger, actuates a relay which opens the probe valve. The gaseous and particulate sample of the cloud rushes in to fill the evacuated plastic bag, and when it is completely inflated (15 cu ft at sampling altitude), the pressure of the sample against a metal plate trips a microswitch. This opens the circuit, causing the valve to close.

After the aircraft have landed and are parked, a diaphragm pump is used to pump the snap-sampler gas contents through a filter (3 to 4 layers of IPC paper) into cylinders. The plastic bags are then removed, and these, together with the filters used in transferring the gas sample, contain the particulate samples.

3.2 SNAP-SAMPLER INSTALLATION

Modification of the first F-84G aircraft for installation of the snap-sampler equipment was done at Wright-Patterson Air Development Center, Dayton, Ohio. To make room for the snap sampler, the aircraft machine guns, ammunition supply, gun radar, gun camera, etc., were removed from the gun deck (Fig. 3.1). The gun deck is located in the upper half of the nose in front of the cockpit (Fig. 3.2). Aluminum liners were fabricated and installed to form a container for the polyethylene bag. The lower liner is shown removed from the gun deck in Fig. 3.3 and is shown installed in Fig. 3.4. The upper liner is shown installed on the underside of the gun-deck cover in Fig. 3.5. Lead blocks, as shown in Fig. 3.1, were added as ballast.

A stainless-steel probe with a $\frac{1}{2}$-in.-diameter diffuser was installed in one of the machine-gun holes as shown in Figs. 3.2 and 3.6. The main body of the probe ($1\frac{1}{2}$-in. ID) was attached to a valve and motor assembly in the gun deck (Fig. 3.6). A polyethylene bag was installed in the lower liner (Fig. 3.7) and attached to the valve as shown in Fig. 3.8. A microswitch (Fig. 3.9) for valve shutoff was installed behind a metal plate and was actuated by pressure on the plate when the bag became inflated.

The snap-sampler actuating switch and indicator light are shown in Fig. 3.10.

Two diffusers are shown in Fig. 3.11. From experimental operations and calculations, it was determined to use a $\frac{1}{2}$-in.-diameter diffuser as shown in Fig. 3.2. Favorable conditions for isokinetic sampling were obtained using a $\frac{1}{2}$-in. diffuser as shown in Table 3.1.

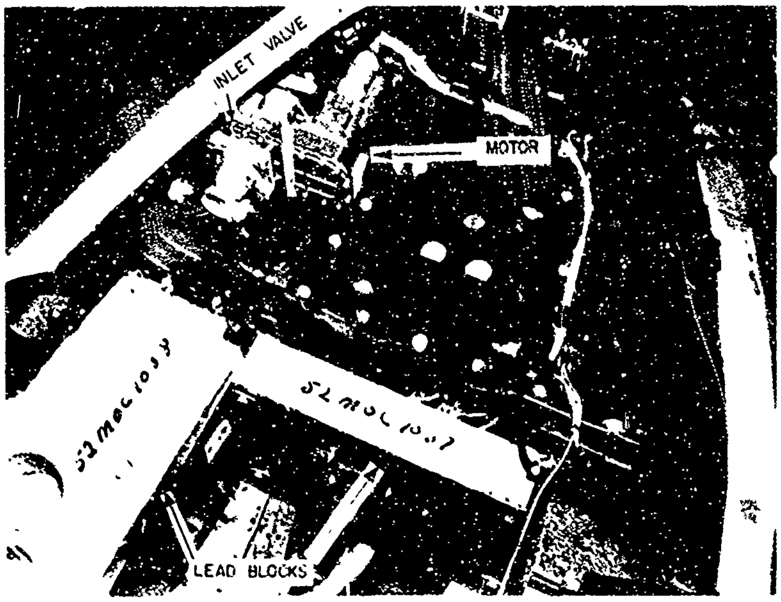

Fig. 3.1—Top view of gun deck with aircraft armament removed.

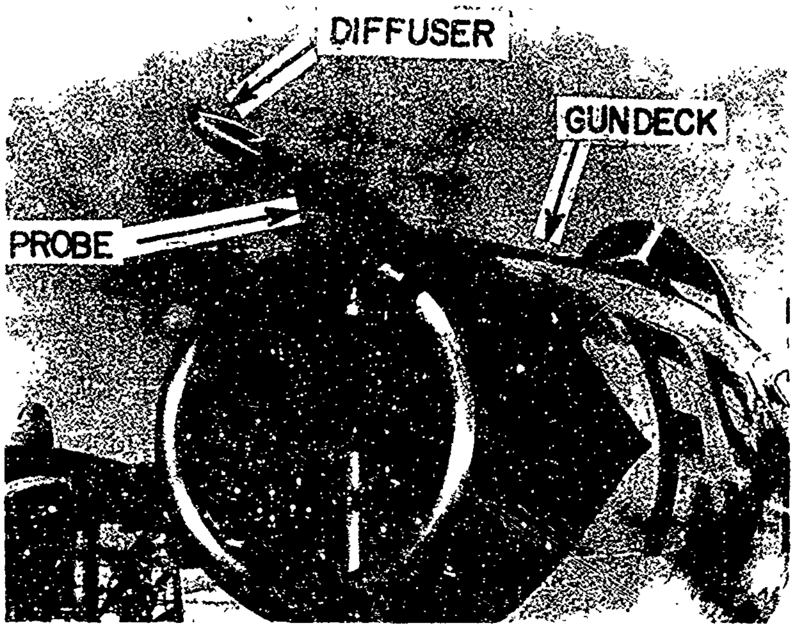

Fig. 3.2—Location of gun deck with probe and diffuser.

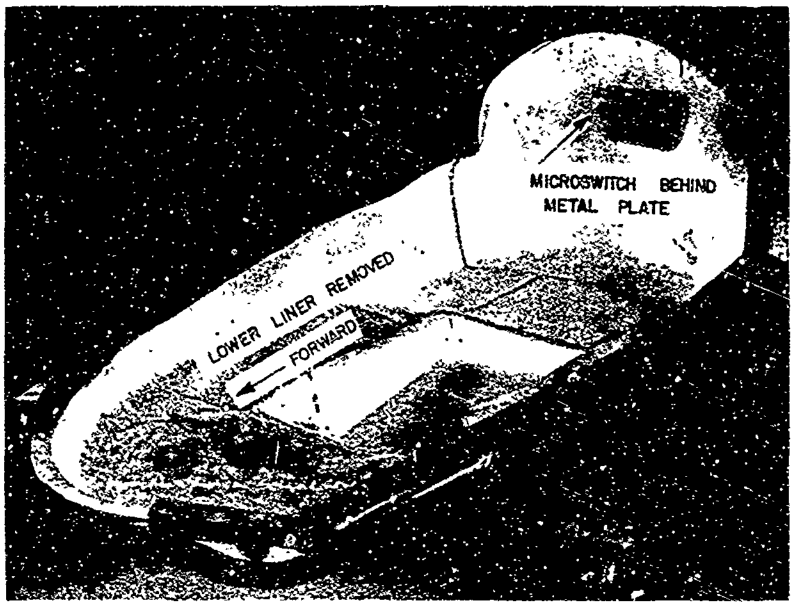

Fig. 3.3—Lower liner removed from gun deck.

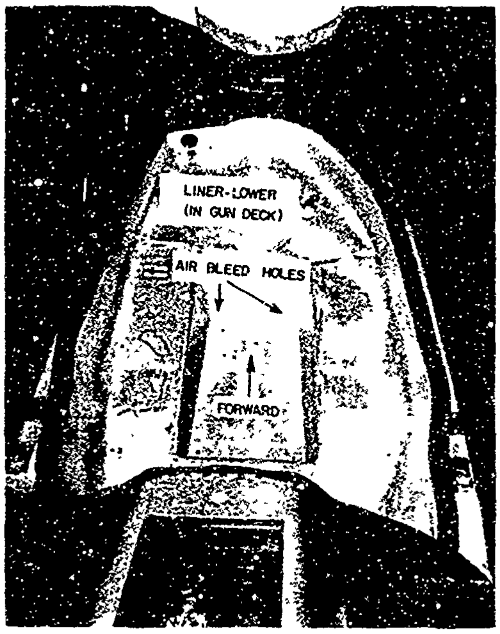

Fig. 3.4—Lower liner installed in gun deck.

Fig. 3.5—Upper liner installed on underside of gun-deck cover.

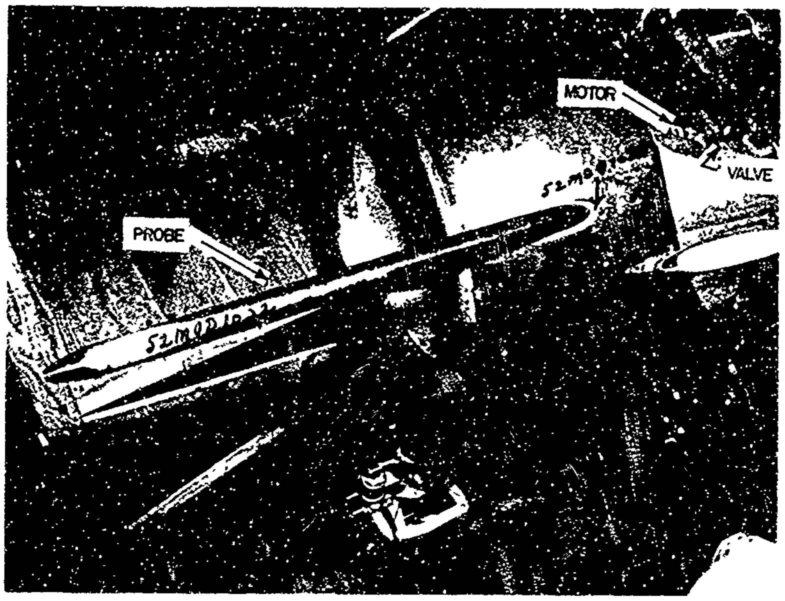

Fig. 3.6—Probe installed through machine-gun hole and attached to valve-motor assembly.

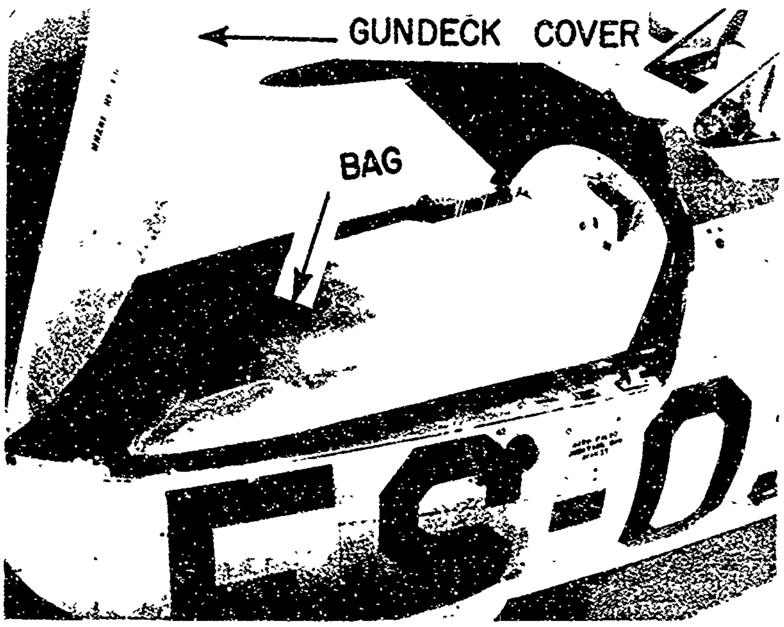

Fig. 3.7—Gun-deck cover opened, showing polyethylene bag installed in gun-deck liner.

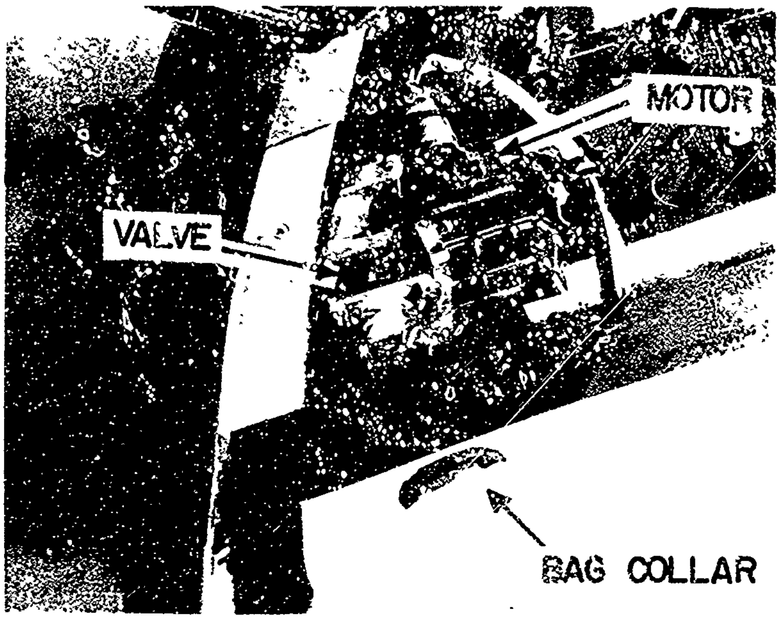

Fig. 3.8—Inlet valve and motor assembly with bag attached.

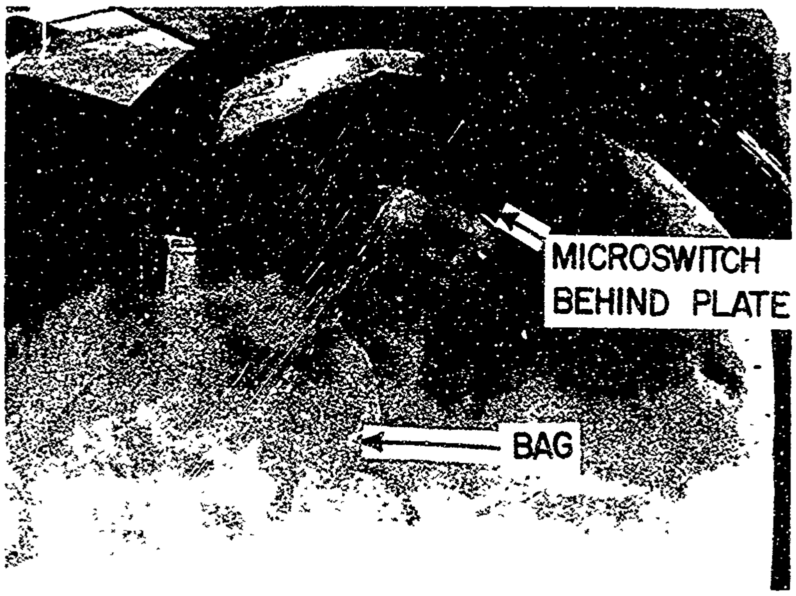

Fig. 3.9—Microswitch and metal plate.

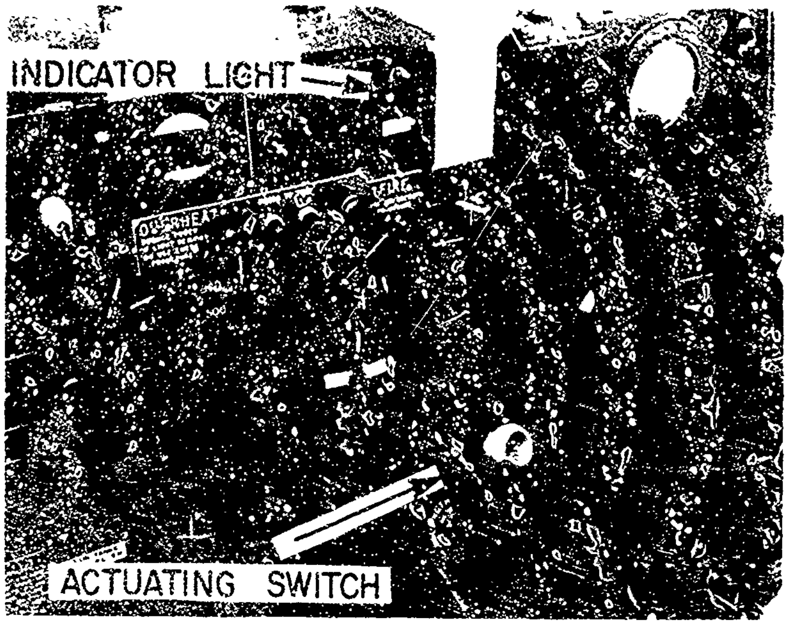

Fig. 3.10—Actuating switch and indicator light.

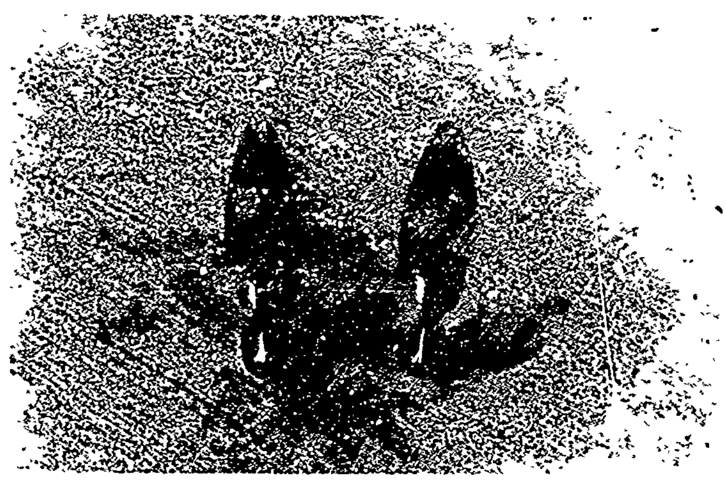

Fig. 3.11—Diffusers. Inlet openings: left, $\frac{5}{16}$ in. diameter; right, $\frac{7}{16}$ in. diameter.

Table 3.1—BAG-FILLING TIME

Altitude, ft	Indicated air speed, mph	Bag-filling time,* sec
42,000	250	11.0
42,000	250	11.0
38,000	290	12.0 s
34,000	320	12.2 s
32,000	310	12.0 s
26,000	380	11.3 s

*Diffuser used to determine the bag-filling times was ½-in. ID. Times marked with the letter "s" were obtained with a stop watch. Volume of the bag is 15 cu ft at sampling altitude.

CHAPTER 4

OPERATIONS

The 16 F-84G sampler aircraft were delivered by aircraft carrier to Kwajalein, where the 561st Fighter Escort Squadron from Bergstrom Air Force Base, Tex., set up headquarters for Operation Ivy. Project 1.3, Sample Collecting (LASL); Project 7.3, Radiochemical and Physical Analyses of Atomic Debris (AFOAT-1 and Tracerlab, Inc.); and Project 5.4b, Fall-out Studies on Eniwetok Atoll (Chemical Corps) were jointly concerned with the F-84G snap samplers. Initial work consisted in checking the installation and operation of all 16 snap samplers and preparing them for the practice missions before the first shot. Polyethylene bags were installed in all F-84G aircraft. Many of the necks of the bags were torn out while they were being installed. (This could be corrected by reinforcing the necks with additional layers of plastic materials.) The pilots were instructed how to obtain samples and how to test the operation of the snap-sampler equipment. After each practice mission corrections were made where they were required.

Detailed preparations were made for the removal and handling of samples on shot day. An outlined procedure, which includes the personnel, equipment required, and procedure to be followed for sample removal, is given in the appendix. Additional preparations were made for alternate plans on sample recovery in case bad weather on either shot day forced the landing of the F-84G sampler aircraft at an alternate landing area. Since these plans were not used at the test site, they are not included in this report.

The day before each of the two shots of Operation Ivy, a final check was made on the operation of the snap samplers, and new polyethylene bags were installed. Mike shot, a surface shot of a thermonuclear device, was detonated at 0715, 1 November 1952 (Marshall Islands time). Eleven of the fourteen F-84G aircraft obtained samples. King shot, an airdrop of a fission bomb, was detonated at 1130, 16 November 1952 (Marshall Islands time). Nine of the fourteen aircraft obtained samples. Sampling data for both shots are given in Tables 4.1 and 4.2.

A B-36 command ship directed the F-84G aircraft during the entire sampling operation. The sampler aircraft departure times were staggered from 1 to 2 hr apart; consequently, the earlier aircraft sampled in a radioactive field of higher average intensity. The pilots were instructed to take samples whenever possible in high-intensity-level radioactive fields, usually an indicated reading of at least 1 r/hr on the radiation-intensity meter that was located in the cockpit. The general radioactivity readings were relatively lower on King shot than on Mike shot. On shot days all samples were removed from the aircraft approximately 30 min after the aircraft had landed and had been parked in the hot parking area.

The equipment on a degassing cart was used to remove the gas from the polyethylene bags, and lead-lined gloves were used in removing the bags. The degassing cart contained a generator, a compressor with evacuating probe containing a changeable filter, and racks to hold two G-1 cylinders. Procedure for sample removal is given in detail in the appendix. The radioactivity levels of the samples and aircraft were not too high; therefore no difficulties were encountered in sample removal.

Table 4.1—SAMPLING DATA FOR MIKE SHOT, 1 NOVEMBER 1952 (H-HOUR, 0715 KWAJALEIN TIME)

Aircraft No.	Time of departure, hr	Time of arrival, hr	Sampling conditions: Altitude, 10^3 ft	Sampling conditions: Indicated air speed, mph	Sampling conditions: Time valve opened, hr	Sample transfer: Gas cylinder and bag No.	Sample transfer: Disposition of bag	Sample transfer: Cylinder pressure, psig	Activity of bag in plane on shot day, mr/hr*
Sniffers:									
042	0610	0950	44	220	0800	S-4	ACC	25	18
032	0610	0950	45	220		S-3	ACC	22	
Red:									
055	0705	1129	42	220	0855	S-5	ACC	14	600
028	0705	1129	42	220	0855	S-8	AFOAT-1	21	1000
030†						S-15	ACC		
040‡							ACC		
White:									
045	0855	1400	42	240	1138	S-7	AFOAT-1	20	70
036	0855	1400	44	240	1130	S-10	AFOAT-1	0	110
046	0855	1400	45	260	1134	S-9, S-11§	ACC	60	200
037¶	0855	1050							
Blue:									
053	1045	1450	42	250	1124				
049	1045	1450	42	260	1224	S-12	ACC	14	60
033	1045	1610	43	220	1330	S-13	ACC	28	40
043	1045	1610	41	220	1424	S-14	ACC		

*Measured approximately 1/2 hr after arrival time of aircraft.
†Landed on Eniwetok.
‡Crashed at sea, total loss.
§Cascade impactor used.
¶Abort due to fuel-line leak.

Table 4.2—SAMPLING DATA FOR KING SHOT, 16 NOVEMBER 1952 (H-HOUR, 1130 KWAJALEIN TIME)

			Sampling conditions			Sample transfer			
Aircraft No.	Time of departure, hr	Time of arrival, hr	Altitude, 10^3 ft	Indicated air speed, mph	Time valve opened, hr	Gas cylinder and bag No.	Disposition of bag	Cylinder pressure, psig	Activity of bag outside of plane on shot day, mr/hr*
Sniffers:									
054	1025	1417	31	300	1327	S-17	AFOAT-1	36	6
049	1025	1417	30	300	1328	S-16	ACC	40	20
Red:									
046	1210	1510	46	240	1403	S-18, S-19	ACC	62	5
053	1210	1510	46	230	1403	S-20†	ACC	24	3
030	1240	1540	32	250	1457				
032	1240	1540	30	250	1457	S-21	ACC	27	25
White:									
037	1300	1600	47	220	1545				
033	1300	1600	31	310	1620				
038‡	1345	1645							
045§	1345	1645							
Blue:									
043	1410	1710	32	290	1530	S-23	AFOAT-1	28	9
055	1410	1710	30	310	1535	S-22	AFOAT-1	54	6
051	1430	1730	25	320	1555	S-24	ACC	26	9
028	1430	1730	25	300	1620	S-25	ACC	56	5

*Measured approximately $1/2$ hr after arrival time of aircraft.
†Cascade impactor used (4-min sample).
‡Abort, landing-gear trouble.
§Abort.

On two occasions (one on each shot), when the gas sample was being transferred from the plastic bag to the G-1 bottle, a cascade impactor was used in the evacuating line. This was done by replacing the standard evacuating probe on the degassing cart with a cascade-impactor assembly system. This system contained two flow lines from an evacuating probe of its own to a filter holder and then on through the compressor and into the G-1 cylinder. One line was a straight flow going through a cascade impactor and filter holder. The other line was a bypass around the impactor to the same filter holder. Both lines contained valves for directing the flow through the system. The bypass valve was shut off completely during the time the gas sample was being evacuated through the cascade impactor. After a predetermined sampling time the bypass valve was opened, and the valve to the impactor was closed. The remainder of the gas was then bypassed into the G-1 cylinder.

Project 7.3 (AFOAT-1) received all gas samples and three bag particulate samples from each shot. The three bag particulate samples were used for initial water-content analysis by AFOAT-1 personnel at the test site. All samples were then processed for shipment by airplane to stateside laboratories. Project 7.3 samples went to Tracerlab, Inc., Boston, Mass., and Argonne National Laboratories, Chicago, Ill., and Project 5.4b samples went to Radiological Division, Chemical Corps Chemical and Radiological Laboratories, Army Chemical Center, Md., for analysis.

CHAPTER 5

RESULTS

The following data are results from the radiochemical analysis of the samples obtained at Operation Ivy.

5.1 SNAP SAMPLERS (MIKE SHOT)

Snap-sampler S13 bag and evacuation filter were analyzed for Sr^{89}, Mo^{99}, Ce^{144}, and Ba^{140}. The S5 bag was analyzed for Mo^{99} and Ce^{144}. The data in Table 5.1 on total number of fissions producing the sample collected are based on the Mo^{99} activities.

Table 5.1—TOTAL NUMBER OF FISSIONS PRODUCING THE SAMPLE COLLECTED

Sampie	Number of fissions
S5 bag	2×10^{11}
S5 filter	Below detectable level
S13 bag	1×10^{10}
S13 filter	1.5×10^{11}

The R factors (the counting-rate ratio In the sample divided by the same ratio for thermal fission of U^{235}) obtained on the samples are given in Table 5.2.

Table 5.2—R FACTORS

Sample	Ce^{144}/Mo^{99}	Ba^{140}/Mo^{99}	Sr^{89}/Mo^{99}
S5 bag	0.14		
S5 filter			
S13 bag	Very low	1.37	0.570
S13 filter	0.97	Cold	Cold

5.2 SNAP SAMPLERS (KING SHOT)

All King shot samples were too low in radioactivity level to be of value for radiochemical

analysis. This may be seen by referring to Table 4.2, under the column heading, "Activity of bag outside of plane on shot day."

5.3 RADIOAUTOGRAPHS

Although no particle-size data were obtained, radioautographs of pieces of two plastic bags that contained particulate samples of the cloud did show the presence of radioactive particles.

5.4 ACTIVITY AND DECAY

The filters in the tips of the evacuating probes used in the transfer of the gas from the plastic bags to the G-1 bottles were counted under a G-M tube. Two of the filters were counted to determine decay rate, and a decay exponent of −2.08 was obtained. Listed in Table 5.3 are the activity data obtained on the snap-sampler evacuation filters (Mike shot) corrected to H + 1 hr.

Polyethylene bag samples 5 and 13 were used for the radiochemical analysis. Bag sample 12 was used for obtaining a decay slope. A curve of the activity vs time for this snap-sampler bag gave a decay slope of −2.35. Listed in Table 5.4 are the decay slopes obtained from different type samples collected at Operation Ivy.

When examined, the slides of the cascade impactors which were used on two sample transfers showed no radioactivity; therefore they were of no value for analysis.

Table 5.3—ACTIVITY DATA ON EVACUATION FILTERS (MIKE SHOT)

Sample No.	Activity at H + 1 hr, dis/min (× 10^8)
2 (background sample)	0.4
3	5.7
4	1.4
5	16.5
7	2.6
8	25.6
10	3.5
12	46.8
13	17.8
14	10.4

Table 5.4—DECAY SLOPES

Type of sample	Decay slope
Snap sampler (evacuation filter)	−2.08
Snap sampler (polyethylene bag)	−2.35
Solid fall-out (gross)	−1.1 to −1.7
Liquid fall-out (gross)	−1.9 to −2.1

CHAPTER 6

ANALYSIS OF DATA

The activity levels of the samples collected were so low that only a limited amount of data could be obtained. A review of the barium to molybdenum and strontium to molybdenum ratios indicates that the R factors obtained are normal. The cerium to molybednum ratio gave the lowest R factor (0.14) that was encountered. This covers data obtained at Operations Greenhouse, Ranger, and Jangle. The reason for this low R factor is being investigated.

Studies on the decay slopes obtained on the evacuation filters and plastic bag (Table 5.4) show that they are comparatively higher than figures obtained from other operations and under other sampling conditions. The decay-slope data on Greenhouse snap-sampler evacuation filters were −1.0 for George shot and −1.6 for Easy shot; on intermittent-particle collector filters, −1.3 for George shot and −1.6 for Easy shot; and on the electrostatic precipitator, −1.4.

The attempt to use cascade impactors in the pump-out system when transferring the gas samples from the plastic-bag collectors to the G-1 cylinders for shipping was decided upon at the last minute because it offered a possible method for size-grading small particles. For an undetermined reason no sample impaction pattern could be found on the slides in either case where the cascade impactor was used. Before any further use of the cascade impactor is made for size-grading small particles, as mentioned above, the method should be evaluated in the laboratory.

The samples generally obtained with the F-84G snap samplers did not approach expectations. It was originally thought that the samples would contain more radioactivity; however, when the over-all cloud-sampling operation is analyzed, the results obtained can be rationalized. The activity concentration of the cloud, the time of sampling, and the manner of sampling all affect the samples obtained. The principal factor that contributed to low-activity samples was the time of actual sampling. This can be seen in studying the sampling data in Tables 4.1 and 4.2. On Mike shot the early aircraft, two Sniffers and the first two aircraft of Red flight, were in a position to obtain samples as expected. The two Sniffer aircraft sampled approximately 45 min after shot time. The pilots in these aircraft were instructed to fly in the outer fringes of the cloud and to obtain background samples. Their main function was to relay the activity and boundary of the cloud to the B-36 command ship. The first two aircraft of Red flight sampled approximately 1 hr and 45 min after shot time. These aircraft were the earliest aircraft to actually conduct cloud sampling. Although the gamma radiation from the cloud was quite high at this time and kept the aircraft on the fringes of the cloud, the activity of the cloud in this region was still sufficiently high to obtain good samples and is so indicated in the sampling data (Table 4.1). At sample-removal time, with the bags still in the aircraft (the first two of Red flight), the bags read 600 and 1000 mr/hr, respectively. The next three aircraft that returned with samples entered the cloud approximately 4 to $4\frac{1}{2}$ hr after shot time. At this time the activity and uniformity of the cloud had dropped appreciably, and the region of

sampling had become very critical. A great deal of the material in the cloud had fallen out, and the high-level-activity regions were spotty. Samples obtained at this time of sampling were relatively low in activity. The remainder of the aircraft sampled approximately 5 to 7 hr after shot time. The time factor again had an effect on samples obtained. Also the design of the snap sampler and the manner in which sampling was conducted affected the samples obtained. The snap sampler in the F-84G aircraft is actuated for sampling by a relay, which the pilot operates by squeezing the gun trigger on the aircraft control stick. The pilots were instructed to sample when their radiation meters indicated they were in a radioactive field of at least 1 r. The F-84G aircraft were operated at 250 to 300 mph indicated air speed, which is 360 to 440 ft/sec; therefore by the time the pilot observed the meter, squeezed the trigger, and the valve opened, the aircraft was no longer in the initial sampling region. Since it takes approximately 12 sec for the bag to fill at sampling altitude, there is no doubt that the aircraft is no longer in the initial sampling region. The above-mentioned factors, together with the length of time (approximately 45 hr) required to courier the samples from Eniwetok to the stateside laboratories, are sufficient to account for the low activity of the samples.

Sampling with the snap sampler, although not 100 per cent adequate, cannot be discarded entirely. Under even partially ideal sampling conditions, good samples may be obtained. It would be more desirable to have a slower type aircraft to carry the snap samplers. This would provide the advantage of being able to sample in a local area for a longer period of time. The principal disadvantage of slower type aircraft is their service ceiling, ranging around 30,000 to 35,000 ft. Drone control aircraft are also more advantageous for sampling purposes. Manned aircraft are limited in entering a radioactive cloud to the exposure dosage of personnel aboard. Drone aircraft are not; therefore they can be flown into the clouds at an earlier time and for a longer duration. Sampling with the snap sampler could be improved by making the actual sampling intermittent so that sampling can take advantage of spotty clouds of high intensity. Methods for obtaining a larger sample through the possible use of pumps and high-pressure gas cylinders should also be investigated.

CHAPTER 7

CONCLUSIONS

From the particulate samples collected and analyzed on Mike shot, the total number of fissions producing the sample collected was on the order of 10^{10} and 10^{11}.

The following R factors were obtained from bag particulate samples: Ce^{144}/Mo^{99}, 0.14; Ba^{140}/Mo^{99}, 1.37; and Sr^{89}/Mo^{99}, 0.57; and, from a filter particulate sample, Ce^{144}/Mo^{99}, 0.97.

The activity data, corrected to H + 1 hr, obtained on the snap-sampler evacuation filters (Mike shot) used when transferring the gas sample from the collecting bags to the shipping cylinders ranged from 1.4×10^3 to 46.8×10^3 dis/min.

The two decay slopes measured on samples, one from the evacuation filters (−2.08) and one from a plastic sampler bag (−2.35), were comparatively higher than decay slopes found from samples obtained at other operations and by other sampling methods.

CHAPTER 8

RECOMMENDATIONS

Sampling with the snap sampler could be improved as follows:

1. Use drone controlled aircraft to carry the snap samplers to enable them to get into higher intensity levels in the cloud.
2. Make the actual sampling intermittent so that sampling can take advantage of spotty clouds of high intensity.
3. Provide for collection of larger samples through modification of the present snap-sampler system in the aircraft.

A field laboratory with all the necessary equipment for radiochemical analysis at the test site would be desirable to carry out early analysis of low-activity samples and to obtain early decay data.

Laboratory evaluation should be made of the use of the cascade impactor in the evacuation line when transferring the snap-sampler gas sample from the collector bag to the shipping cylinders.

Although the snap-sampler bags were generally satisfactory, for future use the necks should be reinforced, and materials other than polyethylene (more suited for handling in radiochemical procedures) should be investigated.

APPENDIX

STANDARD OPERATING PROCEDURE ON SHOT DAY

A. Ground check by technical personnel (D−1).
B. Ready-line check by pilots (H−½).
   1. Senior technicians standing by.
C. Sample-removal equipment required:
   1. Degassing units (2).
   2. Cylinders and probes (16).
   3. Trailer equipped with rack for cylinders, probes, and bags.
   4. Tug for transporting trailer.
   5. Crew stands (4).
   6. Tools: crescent wrenches (4); screwdrivers (6).
   7. Long-handled pins to hold gun-deck lid (2).
   8. Grease pencils, red (4).
   9. Masking tape (2 rolls).
   10. Portable radio transmitter-receiver.
   11. Rad-Safe clothing for 10 men; lead gloves (6 pairs).
D. Degassing and bag removal.
   1. Personnel assemble in safety area (safe distance from aircraft):

Sr. Technician	A	DeWolf, C. F., civ	Schumchyk, M. J., civ
Armament	B	Breene, T., T/Sgt	Slavey, C., S/Sgt
Armament	C	Rudolf, J. R., A/1c	Dunckley, C. O., S/Sgt
Recorder	D	Roady, J. M., Maj	Jones, P. D., 2d Lt
Tug	E	Clippinger, D., T/Sgt	Oneson, T., Pvt

   2. Rad-Safe monitor checks aircraft before sample removal. Armament men hook up sample cylinders and probes. Men E (2) stand by in tug and trailer (safety zone) to handle bottles, bags, and probes.
   3. Armament men wearing lead gloves roll up crew stands and open gun-deck lid. Man C inserts pin while man B gives signal to degas. Man B backs off (10 ft) with crew stand and watches bag. Man C goes to safety zone, leaving crew stand in position.
   4. Men A and D position pump-out cart to degas. Man A (gloves on) proceeds to degas:
      a. Inserts probe in nozzle, airtight.
      b. Pumps down to 26 in. mercury vacuum with bypass valve open.
      c. Closes bypass valve when vacuum reaches 26 in.
      d. Inserts remote power plug and opens nozzle valve (does not touch aircraft).
      e. Opens cylinder valve. Observes vacuum and pressure gauge. (Vacuum should start at 26 in. and drop to approximately 10 in. Vacuum will rise sharply to 15 in. when bag is completely evacuated.)

f. Closes cylinder valve, and observes cylinder pressure when bag is empty.
g. Removes probe and remote power plug.
h. Man D records the following data on data sheet:
   (1) Aircraft number.
   (2) Sample cylinder number.
   (3) Cylinder pressure.
   (4) Remarks: Anything to describe the sample or bag size and condition and pumping-out procedure.

5. Man B signals when degassing is complete and retreats to safety zone. Man D removes pump-out cart to safety zone.
6. Man A proceeds to remove bag:
   a. Using lead gloves, removes clamp and bag collar from nozzle.
   b. Seals up bag collar with masking tape.
   c. Carries bag to box on trailer. With grease pencil man E marks bag with the same number as the gas cylinder used for that particular aircraft.
7. Men B and C remove cylinder (gas sample) and probe from cart and place on trailer. Man E tapes probe ends and marks probe with cylinder number. Installs new cylinder and probe on pump-out cart.
8. Men B and C go in with crew stands and close gun-deck lid. They then move crew stands to safety zone.

REFERENCES

1. B. Siegel et al., Contamination Studies: Particle Size of Material in Cloud, Sandstone Report, Vol. 30, Annex 9, Part IV.
2. E. H. Engquist and T. C. Goodale, Cloud Phenomena: Study of Particulate and Gaseous Matter, Greenhouse Report, Annex 6.1, WT-72.
3. T. H. Mansfield, R. P. Epple, et al., Final Report on Tracerlab Snap Sampler (Including Results of Greenhouse Analysis), Tracerlab, Inc., Boston, Mass., Feb. 25, 1953.

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MEMORANDUM FOR DISTRIBUTION

SUBJECT: Declassification Review of Operation IVY Test Reports

The following 31 (WT) reports concerning the atmospheric nuclear tests conducted during Operation IVY in 1952 have been declassified and cleared for open publication/public release:

WT-602 through WT-607, WT-609 thru WT-618, WT-627 thru WT-631, WT-633, WT-635, WT-636, WT-639, WT-641 thru WT-644, WT-646, and WT-649.

An additional 2 WTs from IVY have been re-issued with deletions. They are:

WT-608, WT-647.

These reissued documents are identified with an "Ex" after the WT number. They are unclassified and approved for open publication.

This memorandum supersedes the Defense Nuclear Agency, ISTS memorandum same subject dated August 17, 1995 and may be cited as the authority to declassify copies of any of the reports listed in the first paragraph above.

John H. Bibb S.

RITA M. METRO
for Chief, Information Security